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GUSTAV YANOVICH VANAG

GUSTAV YANOVICH VANAG (ON HIS 70th BIRTHDAY)

É. Gudrinietse

Gustav Yanovich Vanag, member of the Academy of Sciences of the Latvian SSR, professor, doctor of chemistry, honored worker in science and technology of the Latvian SSR, winner of the republican prize and deputy to the Supreme Soviet of the Latvian SSR, reached his seventieth birthday on March 10, 1961.

Vanag was born in the Tukumsk district of the Kurlyandskii Province. After graduating from Mitavskii gymnasium, he entered the chemical department of the Riga Polytechnic Institute in 1910. During the first World War he worked in Moscow in a chemicopharmaceutical plant (subsequently Chemicopharmaceutical Plant No. 2 VSNKh, and now the Salicylic Plant) as a chemist directing the production of novocaine. In 1921 Vanag completed his studies in the chemical faculty of the University of Latvia and his scientific work through all the subsequent years has been connected with this faculty. While still a student at Riga Polytechnic Institute he began to work as a laboratory assistant for Professor O. Luts. Beginning in 1921 Vanag worked as assistant, dozent and professor of organic chemistry in the organic chemistry department of the University of Latvia; since 1945 he has been at the Latvian State University, and since 1958 at Riga Polytechnic Institute.

In 1932 Vanag defended his dissertation on the subject "Oxidation of an Active Methylene Group"; on July 8, 1946 the Supreme Certifying Commission confirmed him as doctor of chemical sciences and gave him the title of professor. On July 15, 1945 Vanag became the head of the organic chemistry section of the chemical faculty at the Latvian State University and since 1958 he has held the same post at Riga Polytechnic Institute. For two years (from July 1, 1948 to August 22, 1950) Vanag was dean of the chemical faculty.

Since the earliest days of the founding of the Academy of Sciences of the Latvian SSR he has directed the laboratory for the study of diketones. Vanag has successfully combined teaching with scientific research work. Under his direction the dissertations of a great many candidates have been completed; he successfully directs graduate students and brings them up in a spirit of communist morality and in devotion to soviet science.

Vanag's scientific work has been principally devoted to studies of β-diketones, especially of the indanedione-1,3 series. As a result of these studies many physiologically active substances have been found, some of which are used in medicine and produced on a commercial scale. Vanag's first studies were devoted to an investigation of the oxidation of an active methylene group [1-3], to derivatives of bindone [4-7], and to the characterization of amines by means of phthalic anhydride.

His numerous subsequent papers have been devoted principally to the study of derivatives of cyclic β-diketones: to improvement of methods of synthesizing them, to investigation of their reactivity, structure, physiological activity, to their use in analysis, etc.

Nitro derivatives of cyclic β-diketones [8-34]. Under Vanag's direction methods of producing a series of cyclic 2-nitrodiketones-1,3 have been worked out. All the nitroketones obtained have been strong acids and extremely reactive substances; they may be used for the synthesis of many compounds, including those of the heterocyclic series. 2-Nitroindane-dione-1,3 (Ia) has been studied especially thoroughly.
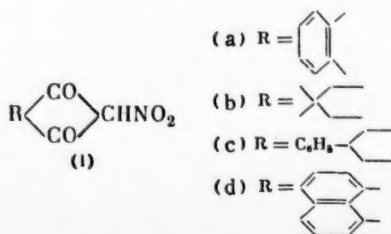
It is a good reagent for the quantitative determination of organic compounds [8], for the determination of formaldehyde [9], etc. As a starting material for organic synthesis, 2-nitroindanedione-1,3 is of especially broad utility [8, 10-19]. With halogens it readily forms 2-halogeno-2-nitroindanediones-1,3(IIa)in which the atom of halogen is highly mobile.

$$R\begin{array}{c}CO\\CO\end{array}C\begin{array}{c}NO_2\\X\end{array}$$

(II)   (IIa) $R = C_6H_4$, $X = Cl$, Br, I.
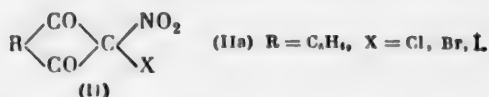
On boiling 2-bromo-2-nitroindanedione-1,3 in a solution of nitrobenzene, ninhydrin is obtained in a 40% yield. 2-Nitroindanedione-1,3 easily forms derivatives of keto groups. The oxime of 2-nitroindanedione-1,3 in the Beckmann rearrangement reaction forms derivatives of isoquinoline. 2-Nitroindanedione-1,3 itself, on reacting with acetic and other anhydrides of the carboxylic acids, and also on reacting with sulfuric acid, forms N-hydroxyphthal-onimide. From 2-nitroindandione-1,3, benzhydrol, xanthydrol, fluorenone and others of the corresponding arylhydryl-nitromethanes were obtained.

Aliphatic alcohols, depending on the quantity of alcohol used, form esters of ω-nitroacetophenone-o-carbox-ylic acid or isonitrosoindanedione [8], which was also investigated by Vanag [20-23].

Other cyclic 2-nitroderivatives of β-diketones, namely, dimedone (Ib) [24-26], 5-phenylcyclohexanedione-1,3 (Ic) [27], perinaphthindanedione-1,3 (Id) [28], dimethoxyindanedione-1,3 and bindone [29-34] were also studied under Vanag's direction.

Sulfonic acids of cyclic β-diketones [35-44]. Cyclic β-diketones, indanedione-1,3, dimedone, phenidone (5-phenylcyclohexanedione-1,3), perinaphthindanedione-1,3, 2-arylindanediones-1,3 and others easily form the cor-responding 2-sulfonic acids (III) [35-44].

$$R\begin{array}{c}CO\\CO\end{array}C\begin{array}{c}X\\SO_3H\end{array}$$

(III)

$R = $; ; C_6H_5- ; ; $X = H$,

$R = $; $X = C_6H_5$; $C_6H_5CH_2-$.
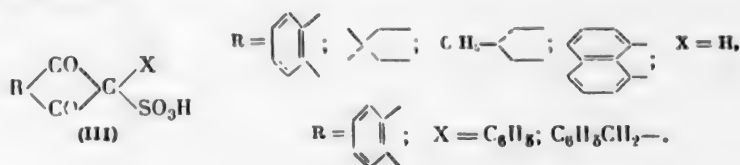
The sulfonation reaction proceeds with dioxanesulfotrioxide (D-SO₃), a mixture of sulfuric acid and anhydrides of carboxylic acids, chlorosulfonic acid, and sulfuric anhydride. The sulfonic acids form benzylthiouronium salts, which may be used for the identification of the sulfonic acids of β-diketones. The sulfonation of 2-phenylindane-dione-1,3 by means of chlorosulfonic acid gives 2-phenylindanedione-1,3-sulfo-4'-acid (IV), which is red in color and has properties reminiscent of aromatic sulfonic acids.

$$SO_3H$$

(IV)
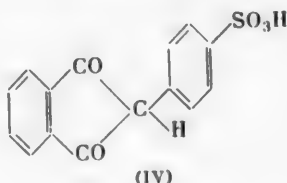
Polynuclear derivatives from cyclic β-diketones [45-61]. The cyclic β-diketones, indanedione-1,3 and dimedone undergo condensation reactions with carbonyl compounds leading to the formation both of 2-arylindene-β-diketones and gem-diindanedionyl- and also bisdimedonyl derivatives. Gem-derivatives easily form the corre-sponding derivatives of the pyrans. The latter, on reacting with ammonia or amines, form derivatives of dihydro-pyridine. It appears that the dihydropyridines are easily obtained both from diindanediones and also from indane-dione-1,3 on heating with the corresponding carbonyl compounds and ammonium acetate in a solution of glacial acetic acid. Dimedone reacts similarly to indanedione-1,3; in this case derivatives of acridine are formed. Am-monium acetate also reacts with alkyl- and other 2-substituted indanediones, forming the corresponding imines.

2-Arylhydrazono-β-diketones [62-69]. Indanedione-1,3 and other cyclic β-diketones readily condense with diazotized aromatic amines. 2-Arylhydrazonoindanediones-1,3 and 2-arylhydrazonodimedones in pyridine solution form complex compounds with salts of silver, copper, cobalt, nickel, etc. These complexes may be used as mordant

dyes. The sodium salt of the ethyl ester of indanedionecarbonic acid with diazotized aromatic amines forms the corresponding ethyl ester of arylazoindanedionecarboxylic acid. Azo derivatives are also obtained from 2-aryldimedones.

Physiologically active substances in the indanedione-1,3 series [70-84]. Of greatest practical interest is 2-phenylindanedione-1,3, which is a good anticoagulant for blood. Its derivatives, such as halogen-, nito-, hydroxymethyl-, and others also possess anticoagulant properties. So do the 2-arylindanediones-1,3. It appears that the following may be successfully used as rodent killers (2-diphenylacetylindanedione-1,3, pivalylindanedione, etc.

A new class of compounds of the indanedione series is of great interest; this consists of the 2-amino-2-aryl-indanediones-1,3. These are substances with narcotic, anti-convulsive and other actions. To these may be added the hydrochloric acid salts of 2-methylamino-2-phenylindanedione-1,3 ("Metamfidon") and of 2-ethylamino-2-phenylindanedione-1,3 ("Etamfon").

Under Wanag's direction extensive investigations of the iodonium derivatives of dimedone [85-90] have been carried out; through the synthesis of new β-diketones [91-95], through the chloromethylation of aromatic compounds [96-99], by study of the pyridine fraction of sapropelic rosin [100-102], by amino derivatives of fluorene [103-104], etc.

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ations of the abbreviations as given in the original Russian journal. *Some or all of this peri-
odical literature may well be available in English translation.* A complete list of the cover-to-
cover English translations appears at the back of this issue.

LAYERING IN TERNARY RECIPROCAL SYSTEMS
OF SALTS OF ORGANIC AND INORGANIC ACIDS

N. M. Sokolov, N. M. Tsindrik, and O. I. Dmitrevskaya

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Layering in mixtures of fused salts was first discovered by I. A. Kablukov [1]. In double systems of typical salts, layering rarely occurs; it is found considerably more frequently in systems of slightly dissociated salts [2], and also in systems containing organic acids [3-5], and in ternary reciprocal systems [6]. Over 80 ternary reciprocal systems in which layering occurs are now known [6].

While layering was known only in singular systems, it was connected with the high thermal effect of the reaction [7]. As a matter of fact, layering often occurs in reciprocal systems [8-15], and in a number of systems an increase in the degree of singularity is accompanied by an increase in the region of layering [8-11]. Then, however, systems were found with sharply expressed singularity and a very high thermal reaction effect, but which did not show layering [6]. A number of typical reversible systems in which layering occurs are also known [14-17]; in alkali-nitrate exchange systems with a large thermal effect there is no layering, while with those having a smaller effect it occurs [14]. Consequently, layering and singularity are phenomena which often coincide, but there is no systematic relation between them. D. S. Lesnykh and A. G. Bergman see the cause of layering in the different configuration of the outer electron shell of the ions composing the stable pair of salts. Layering in systems containing ions with similar outer electron shells, in their opinion, is possible in case the ions are located at large distances from each other in the sub-group of the Mendeleev periodic system [13, 18]. According to the data of I. N. Belyaev, layering may be observed when a typical salt and a weakly polar compound interact [6].

Layering in ternary reciprocal systems with salts of organic acids was first discovered in our laboratory [19-24].

The present paper gives the results of studies of ternary reciprocal systems of lithium, sodium, and potassium salts of fatty acids and of thiocyanates and nitrates of these metals. All systems were divided into two exchange series—thiocyanates and nitrates. In each series there are three groups of systems, each of which is united by one double system which is common to them. By taking these together it is possible, within the limit of one exchange series, to draw some conclusions on the influence on layering both of a combination of cations, and of the substitution of one salt of a fatty acid for another, while comparison of single type systems of the thiocyanate and nitrate series shows the influence of the anion of the inorganic acid on the process. Systems of the thiocyanate exchange series are presented in Table 1, and those of the nitrate series in Table 2.

EXPERIMENTAL SECTION AND DISCUSSION OF RESULTS

The work was carried out by the visual-polythermic method of physical chemical analysis according to the generally used procedures. The melting points of the components of the systems are as follows: $LiNO_3-256°$, $LiCNS-266°$, $HCOOLi-273°$, $CH_3COOLi-284°$, $C_2H_5COOLi-329°$, $C_3H_7COOLi-330$, $C_4H_9COOLi-312°$, $C_5H_{11}COOLi-297°$, $NaNO_3-308°$, $NaCNS-311°$, $HCOONa-258°$, $CH_3COONa-331°$, $C_2H_5COONa-298°$, $C_3H_7COONa-330°$, $C_4H_9COONa-357°$, $C_5H_{11}COONa-365°$, $KNO_3-337°$, $KCNS-174°$, $HCOOK-167°$, $CH_3COOK-301°$, $C_2H_5COOK-365°$, $C_3H_7COOK-404°$, $C_4H_9COOK-444°$, $C_5H_{11}COOK-444.5°$, $C_6H_{13}COOK-450°$.

All ternary reciprocal systems (there are 37 of them) composing the two exchange series are related to irreversible, diagonal systems. For each group of systems of a given series, the stable pair of salts is of one and the same type. For example, for the systems of the first group of the thiocyanate exchange series such a pair would be sodium thiocyanate and the lithium salt of a fatty acid; in the second group it would be the sodium salt of a fatty acid and potassium thiocyanate. Of this pair of salts, one and the same salt of each group will be more stable, and with increasing

TABLE 1. First Series of Systems

Systems	Stable pair	More stable salt of the stable pair	Layer-ing
Group 1			
Li, Na $\parallel$ CNS, HCOO	NaCNS—HCOOLi	NaCNS	No
Li, Na $\parallel$ CNS, CH_3COO	NaCNS—CH_3COOLi	NaCNS	No
Li, Na $\parallel$ CNS, C_2H_5COO	NaCNS—C_2H_5COOLi	NaCNS	Yes
Li, Na $\parallel$ CNS, C_3H_7COO	NaCNS—C_3H_7COOLi	NaCNS	Yes
Li, Na $\parallel$ CNS, C_4H_9COO	NaCNS—C_4H_9COOLi	NaCNS	Yes
Li, Na $\parallel$ CNS, $C_5H_{11}COO$	NaCNS—$C_5H_{11}COOLi$	NaCNS	Yes
Group 2			
Na, K $\parallel$ CNS, HCOO	HCOONa—KCNS	HCOONa	No
Na, K $\parallel$ CNS, CH_3COO	CH_3COONa—KCNS	CH_3COONa	No
Na, K $\parallel$ CNS, C_2H_5COO	C_2H_5COONa—KCNS	C_2H_5COONa	No
Na, K $\parallel$ CNS, C_3H_7COO	C_3H_7COONa—KCNS	C_3H_7COONa	No
Na, K $\parallel$ CNS, C_4H_9COO	C_4H_9COONa—KCNS	C_4H_9COONa	No
Na, K $\parallel$ CNS, $C_5H_{11}COO$	$C_5H_{11}COONa$—KCNS	$C_5H_{11}COONa$	No
Na, K $\parallel$ CNS, $C_6H_{13}COO$	$C_6H_{13}COONa$—KCNS	$C_6H_{13}COONa$	Yes
Group 3			
Li, K $\parallel$ CNS, HCOO	HCOOLi—KCNS	HCOOLi	No
Li, K $\parallel$ CNS, CH_3COO	CH_3COOLi—KCNS	CH_3COOLi	Yes
Li, K $\parallel$ CNS, C_2H_5COO	C_2H_5COOLi—KCNS	C_2H_5COOLi	Yes
Li, K $\parallel$ CNS, C_3H_7COO	C_3H_7COOLi—KCNS	C_3H_7COOLi	Yes
Li, K $\parallel$ CNS, C_4H_9COO	C_4H_9COOLi—KCNS	C_4H_9COOLi	Yes
Li, K $\parallel$ CNS, $C_5H_{11}COO$	$C_5H_{11}COOLi$—KCNS	$C_5H_{11}COOLi$	Yes

TABLE 2. Second Series of Systems

Systems	Stable pair	More stable salt of the stable pair	Layer-ing
Group 1			
Li, Na $\parallel$ NO_3, HCOO	$NaNO_3$—HCOOLi	$NaNO_3$	No
Li, Na $\parallel$ NO_3, CH_3COO	$NaNO_3$—CH_3COOLi	$NaNO_3$	No
Li, Na $\parallel$ NO_3, C_2H_5COO	$NaNO_3$—C_2H_5COOLi	$NaNO_3$	Yes
Li, Na $\parallel$ NO_3, C_3H_7COO	$NaNO_3$—C_3H_7COOLi	$NaNO_3$	Yes
Li, Na $\parallel$ NO_3, C_4H_9COO	$NaNO_3$—C_4H_9COOLi	$NaNO_3$	Yes
Li, Na $\parallel$ NO_3, $C_5H_{11}COO$	$NaNO_3$—$C_5H_{11}COOLi$	$NaNO_3$	Yes
Group 2			
Na, K $\parallel$ NO_3, HCOO	HCOONa—KNO_3	HCOONa	No
Na, K $\parallel$ NO_3, CH_3COO	CH_3COONa—KNO_3	CH_3COONa	No
Na, K $\parallel$ NO_3, C_2H_5COO	C_2H_5COONa—KNO_3	C_2H_5COONa	No
Na, K $\parallel$ NO_3, C_3H_7COO	C_3H_7COONa—KNO_3	C_3H_7COONa	No
Na, K $\parallel$ NO_3, C_4H_9COO	C_4H_9COONa—KNO_3	C_4H_9COONa	Yes
Na, K $\parallel$ NO_3, $C_5H_{11}COO$	$C_5H_{11}COONa$—KNO_3	$C_5H_{11}COONa$	Yes
Group 3			
Li, K $\parallel$ NO_3, HCOO	KNO_3—HCOOLi	KNO_3	No
Li, K $\parallel$ NO_3, CH_3COO	KNO_3—CH_3COOLi	KNO_3	Yes
Li, K $\parallel$ NO_3, C_2H_5COO	KNO_3—C_2H_5COOLi	KNO_3	Yes
Li, K $\parallel$ NO_3, C_3H_7COO	KNO_3—C_3H_7COOLi	KNO_8	Yes
Li, K $\parallel$ NO_3, C_4H_9COO	KNO_3—C_4H_9COOLi	KNO_3	Yes
Li, K $\parallel$ NO_3, $C_5H_{11}COO$	KNO_3—$C_5H_{11}COOLi$	KNO_3	Yes
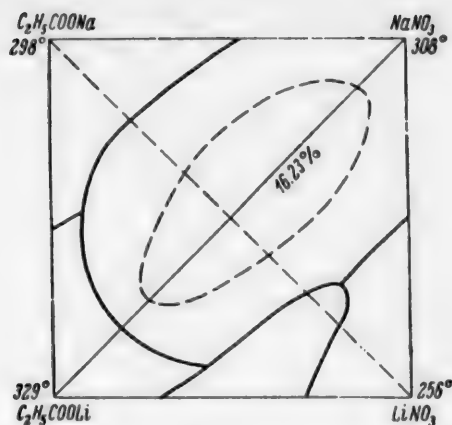
Fig. 1. Irreversible-reciprocal system with layering: Li, Na‖ C₂H₅COO, NO₃.
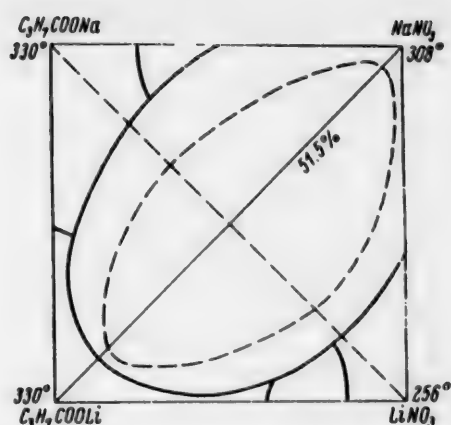
Fig. 2. Irreversible-reciprocal system with layering: Li, Na‖ C₃H₇COO, NO₃.
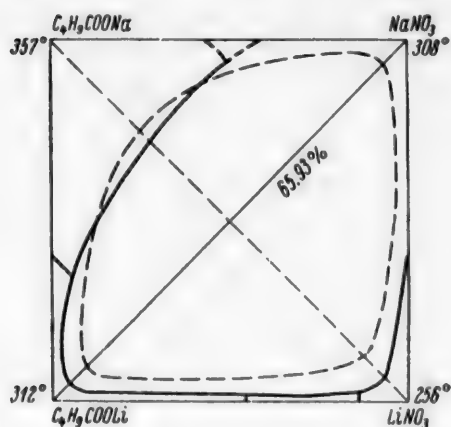
Fig. 3. Irreversible-reciprocal system with layering: Li, Na‖ C₄H₉COO, NO₃.
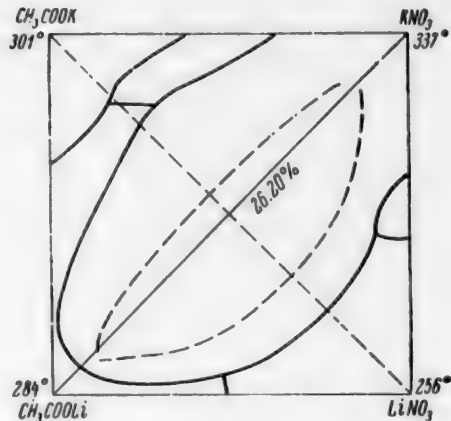
Fig. 4. Irreversible-reciprocal system with layering: Li, K‖ CH₃COO, NO₃.

length of the fatty acid radical it pushes the less stable one against the stable diagonal. In each of these six groups of systems, the direction of the exchange reaction is the same as in the first system (formate). Increase in the number of carbon atoms in the radical of the fatty acid salt increases the degree of displacement of equilibrium, and wherever there is layering, there the lens of layering grows. Within the lens of layering in the Figures there are numbers indicating the portion (in %) of the surface of the liquids that touches the lens of layering (Fig. 1-4).

In the nitrate and thiocyanate series in the presence of Li and Na, layering sets in in the propionate system; in the presence of Na and K in the nitrate exchange system layering is observed in the valerate system, while in the thiocyanate series it only occurs in the enanthate system. Consequently, the participation of Li in systems facilitates layering and especially when Li is accompanied by K, i.e., when the metals are located in a group of the periodic system separated by one period. Whether or not this confirms the previously expressed theory [14], or whether this depends on the properties of the Li ion— its special structure, small radius, large polarizing action, etc.,is difficult to say, as long as studies on systems containing rubidium and caesium have not been completed (we have started on them). Judging from the data in the literature, the effect is more likely due to the specific character of the Li ion, since in the Li, K, ‖ NO₃, CH₃COO system layering occurs, while in the Cs, K, ‖ NO₃, CH₃COO system it does not [26].

By examining the systems of the thiocyanate and nitrate series with one and the same group of metals, one may conclude that the NO₃ anion facilitates layering more than the CNS anion. This is shown in Table 3.

TABLE 3. Comparison of the Systems of the I and II Series

Systems	Layering	Portion of the stable diagonal occupied by layering, %
Na, K ‖ C_4H_9COO, NO_3	Yes	52.5
Na, K ‖ C_4H_9COO, CNS	No	—
Na, K ‖ $C_5H_{11}COO$, NO_3	Yes	74
Na, K ‖ $C_5H_{11}COO$, CNS	No	—
Li, Na ‖ C_2H_5COO, NO_3	Yes	24.5
Li, Na ‖ C_2H_5COO, CNS	Yes	17.5
Li, K ‖ CH_3COO, NO_3	Yes	80
Li, K ‖ CH_3COO, CNS	Yes	55
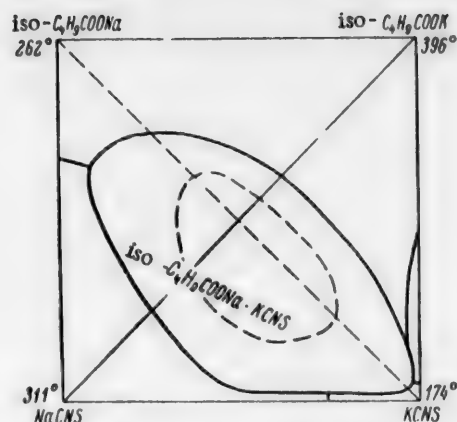
Fig. 5. Irreversible-reciprocal system with layering Na, K ‖ iso-C_4H_9COO, CNS.

Tables 1 and 2 show data for systems formed by salts of normal fatty acids. We determined that in all systems formed from isobutyric and isovaleric acids layering occurs if it occurs in an analogous system with a normal salt of a fatty acid. Thus, in the systems Li, Na ‖ NO_3, iso-C_3H_7COO; Li, Na ‖ NO_3, iso-C_4H_9COO; Na, K ‖ NO_3, iso-C_4H_9COO; Li, K ‖ NO_3, iso-C_3H_7COO; Li, K ‖ NO_3, iso-C_4H_9COO; Li, Na ‖ CNS, iso-C_3H_7COO; Li, K ‖ CNS, iso-C_4H_9COO; Li, Na ‖ CNS, iso-C_4H_9COO; Li, K ‖ CNS, iso-C_3H_7COO layering takes place. In the systems Na, K ‖ NO_3, iso-C_3H_7COO; Na, K ‖ CNS, iso-C_3H_7COO it does not occur.

Thus, branching of the chain of carbon atoms does not prevent layering; instead it even favors it. This follows from the fact that in the system Na, K ‖ CNS, n-C_4H_9COO, no layering occurs, while in a system formed with a salt of isovaleric acid it does [19-23]. It is true that in this case it occurs for a special reason: The heteroionic compound iso-$C_4H_9COONa \cdot KCNS$ formed in the melt has limited miscibility with components of the system (Fig. 5).

In conclusion it should be pointed out that the Li, K ‖ NO_3, CH_3COO system (Fig. 4) was previously described [25] as a system without layering; our investigations have shown that layering does occur in the system, and the lens of layering occupies 26.2% of the total surface of the liquids of the system [22]. In the lateral system $LiNO_3 - KNO_3$ the compound $LiNO_3 \cdot KNO_3$ was found by us for the first time [22].

SUMMARY

1. Thirty-seven ternary reciprocal systems of salts of nitric or thiocyanic or organic acids were divided into two series of exchange systems (with NO_3 and CNS), each of which was further divided into three groups with common components on one side.

2. Within each group of systems the direction of the exchange reaction was identical. In subsequent transition to systems where the salts of the fatty acids contain a larger number of carbon atoms, the irreversibility of the exchange reaction gradually increases, and finally layering occurs.

3. A combination of cations, in the presence of identical anions, has an influence on layering; the lithium ion especially favors the onset of layering.

4. The character of the anion of the inorganic acid also influences layering; the nitrate ion favors layering more than the thiocyanate ion.

5. In ternary reciprocal systems, composed of salts of inorganic and organic acids, layering is apparently always possible. It sets in if, in a given combination of cations and anions or inorganic acids, the corresponding anion of an organic acid is introduced. Thus, in a given combination of anions and a given cation, another cation may be selected which will give a system in which layering occurs.

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THE REDUCTION OF SOME SULFONAMIDES
AT THE DROPPING MERCURY CATHODE

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Recently a large number of sulfonamides of different composition and structure have been synthesized which have found use as chemotherapeutic agents.

The polarographic properties of a series of sulfonamides have been described in a paper [1], and it was shown that some of them contain polarographically active groups. Thus, for example, sulfathiazole, sulfazole and some others on reduction at a dropping mercury cathode give clear-cut diffusion waves which may be used for quantitative analysis.

In the present paper data are given on the reduction at the dropping mercury cathode, in the presence of various electrolytes, of (I) "sulzimide"; (II) "urosulfane"; (III) "sulgin"; (IV) "ethazole"; (V) "sulfodimesine," (VI) "disulformin."
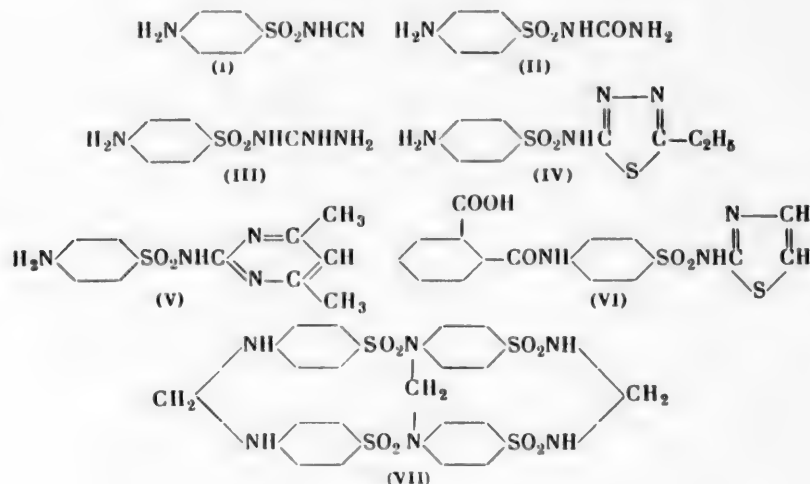
EXPERIMENTAL

As background for polarography a large amount of a 0.5 N aqueous solution of lithium, potassium, ammonium or calcium chlorides, potassium nitrate, 0.2 N sodium sulfate, 0.5 N hydrochloric acid and sodium hydroxide, 0.2 M tetraethylammonium iodide and buffer solutions with pH from 3 to 11 consisting of acetic acid and ammonia were used.

For polarography of sulfonamides that were difficult to dissolve in water 40% solutions of alcohol were used. The polarograms were taken on a visual polarograph, with the exception of "phthalzol", the polarogram of which was obtained with the aid of an electron integrodifferentiating polarograph. A capillary was used for the cathode, the flow $m^{2/3}t^{1/6}$ of which was 1.00 $mg^{2/3}sec^{-1/2}$ with the circuit open. A saturated calomel semi-element was used as the anode, in comparison with which the half-wave potentials are given.
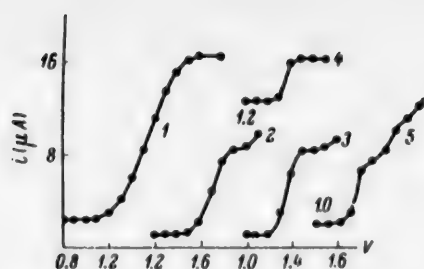
Fig. 1. Reduction waves in the presence of
0.5 N LiCl. 1) "sulzimide"; 2) "urosulfane";
3) "sulfodimesine"; 4) "disulformin";
5) "ethazol."

TABLE 1. i_d and $E_{1/2}$ of "Sulzimide"
in the Presence of a Background of Various Electrolytes

Background	i_d (µA)	$E_{1/2}$ (V)
0.5 N LiCl	15.4	—1.54
0.5 N KCl	15.0	—1.48
0.5 N NH$_4$Cl	15.6	—1.48
0.5 N CaCl$_2$	15.2	—1.70
0.5 N KNO$_3$	14.1	—1.44
0.2 N Na$_2$SO$_4$	13.0	—1.49
0.2 M (C$_2$H$_5$)$_4$NI	15.4	—1.56

"Sulzimide" (I) dissolves easily in water and therefore aqueous solutions were used for polarography.

The experiments that were carried out showed that "sulzimide" belongs to the group of compounds which are reduced at the dropping mercury cathode. One can observe well marked diffusion waves on the polarization curves (Fig. 1, curve 1).

In Table 1 are shown the diffusion currents and the potentials of the half-waves of "sulzimide" in the presence of a background of varying composition at a concentration of $4.1 \cdot 10^{-3}$ M.

As can be seen from the data in the table, the magnitude of the diffusion current of "sulzimide" is almost identical in the presence of all the electrolytes studied, with the exception of solutions of sodium sulfate and potassium nitrate, in which the diffusion current is somewhat smaller.

When using a solution of potassium nitrate as background in polarographing, the limiting current of "sulzimide" is poorly shown, while in the presence of a background containing a solution of potassium chloride, the diffusion wave is very stretched out. Moreover, in this solution the half-wave potential of "sulzimide" is pushed strongly in a negative direction.

There is direct proportionality between the magnitude of the diffusion current and the concentration of "sulzimide".

The half-wave potential of "sulzimide" depends somewhat on its concentration, and is displaced in a negative direction with increasing concentration. Thus, on changing the concentration of "sulzimide" in the solution from $1 \cdot 10^{-3}$ to $4.1 \cdot 10^{-3}$ M, the half-wave potential changes from —1.47 to —1.54 v.

"Urosulfane" (II). It was possible to polarograph "urosulfane" and to get diffusion waves of this compound only in the presence of a 0.5 N solution of lithium chloride and a 0.2 M solution of tetraethyl ammonium iodide (Fig. 1, curve 2). Within a comparatively small concentration range, the diffusion current of "urosulfane" is linearly dependent on its concentration.

The half-wave potential of "urosulfane" in the presence of a 0.5 N solution of lithium chloride is — 1.7 v, while in the presence of a 0.2 M solution of tetraethylammonium iodide it is —1.6 v.

"Sulgin" (III) is apparently not reduced at the dropping mercury cathode. The diffusion currents of this compound were not obtained, and in a 0.2 M solution of tetraethylammonium iodide the onset of reduction was greater than -2.0 v.

"Ethazole" (IV). The polarograms of "ethazole" were obtained in solutions containing 40% alcohol. In solutions of lithium and calcium chlorides and in solutions of tetraethylammonium iodide at "ethazole" concentrations of the order of $6 \cdot 10^{-3}$ M and above, polarization curves with one diffusion wave were obtained.

The potential of the half-wave is —1.54 v. On decreasing the concentration of "ethazole" in the solutions the wave divides into two (Fig. 1, curve 5), the diffusion current of the first wave being somewhat greater than the diffusion current of the second wave. The half-wave potential of the first wave is —1.36 v, and that of the second is —1.7 v. The diffusion current of the first, second and total wave is proportional to the concentration of "ethazole"

TABLE 2. i_d and $E_{1/2}$ of "sulfodimesine"
in the Presence of Various Electrolytes

Background	i_d (μA)	$E_{1/2}$ (V)
0.5 N LiCl	3.85	−1.36
0.5 N KCl	3.96	−1.35
0.5 N CaCl₂	3.63	−1.33
0.5 N NH₄Cl	8.47	−1.30
0.2 N Na₂SO₄	3.63	−1.36
0.2 M (C₂H₅)₄I	3.74	−1.40
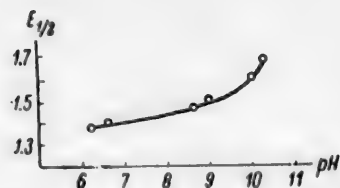
Fig. 2. Dependence of $E_{1/2}$ on
the value of pH for "phthalazole".

in the solution. On increasing the concentration of alcohol
in the solution to 60%, the "ethazole" waves merge with
each other and with the background.

In the presence of potassium and ammonium chlorides and sodium sulfate, only one wave is observed which
has a potential of −1.36 v. The second wave under these conditions merges with the reduction wave of the back-
ground. It was not possible to obtain diffusion currents for "ethazole" in buffer solutions.

"Sulfodimesine" (V) is practically insoluble in water and therefore a standard alcohol solution was used and
solutions polarographed that contained 40% of alcohol.

In Table 2 are shown the diffusion currents and half-wave potentials of "sulfodimesine" in the presence of
various electrolytes at an $8 \cdot 10^{-3}$ M concentration.

As can be seen from the data in Table 2, the diffusion current and half-wave potential of "sulfodimesine" are
almost identical in all the electrolytes used by us. An exception was solutions of ammonium chloride, in which the
diffusion current of "sulfodimesine" was almost two times greater. A similar picture is also observed in some buffer
solutions with a pH of from 6.18 to 10.3. In these solutions with an identical concentration of "sulfodimesine," the
diffusion currents are twice as great, for example, as in the case of 0.5 N lithium chloride.

With increasing values of the pH of the buffer solution, the magnitude of the limiting current does not remain
absolutely constant for a given concentration, but decreases slightly. For example, at pH 6.18 i_d = 5.5 μa, while
at pH 10.3 i_d = 4.4 μa. At the same time a straight line dependence between the diffusion current and the concen-
tration of "sulfodimesine" is maintained for all salt solutions and buffer solutions. Figure 2 shows graphically the
dependence of the half-wave potential of "sulfodimesine" on the pH of the buffer.

With increasing values of the pH of the solution, the half-wave potential of "sulfodimesine" is displaced in a
negative direction.

"Phthalazole" (VI). Water-alcohol solutions containing small quantities of gelatin were used for polarograph-
ing "phthalazole." Experimental data are shown in Table 3.

In 0.5 N solutions of lithium chloride and 0.2 M solutions of tetraethylammonium iodide, "phthalazole" is
reduced at the dropping mercury cathode, giving three waves on the polarogram (Fig. 3). In solutions of tetraethyl-
ammonium iodide the heights of the waves are almost identical, are not distorted by maxima and are proportional
to the concentration of "phthalazole." In the presence of other salts shown in Table 3, "phthalazole" gives only
two reduction waves the maxima on which in some solutions are not always suppressed.

In buffer solutions with pH 5.1-9.0 only the second reduction wave of "phthalazole" is observed, with a half-
wave potential of −1.54 v. There is a linear dependence between the magnitude of the diffusion current of the
second wave and the concentration of "phthalazole." The diffusion current of the second wave for a given "phthal-
azole" concentration, as in the case of "dimesidine," depends on the magnitude of the pH of the buffer solution.
This dependence is shown in Fig. 4.

"Disulformin" (VII) is practically insoluble in water, alcohol, and dilute mineral acids, but is easily soluble
in caustic alkalies. A standard solution was prepared by dissolving a given weight of "disulformin" in a 0.04 N solu-
tion of sodium hydroxide. The distinct polarographic wave of "disulformin" is observed on the sodium hydroxide
background. The half-wave potential is −1.7 v. At constant alkali concentration, the height of the waves is pro-
portional to the concentration of "disulformin" in the solution. The diffusion current of "disulformin" depends on

TABLE 3. i_d and $E_{1/2}$ of "Phthalazole" in the Presence of Various Electrolytes (concentration $6 \cdot 10^{-3}$ M)

Background	i_d' (μA)	i_d'' (μA)	i_d''' (μA)	$E_{1/2}'$ (V)	$E_{1/2}''$ (V)	$E_{1/2}'''$ (V)
0.5 N LiCl	3.95	0.85	7.0	—1.32	—1.54	—1.93
0.5 N KCl	3.50	1.75	—	—1.33	—1.50	—
0.5 N NH_4Cl	4.75	7.0	—	—1.33	—1.47	—
0.5 N KNO_3	6.80	1.30	—	—1.32	—1.52	—
0.2 N Na_2SO_4	2.90	1.0	—	—1.32	—1.52	—
0.2 N $(C_2H_5)_4NI$	3.10	3.20	3.9	—1.29	—1.51	—1.92
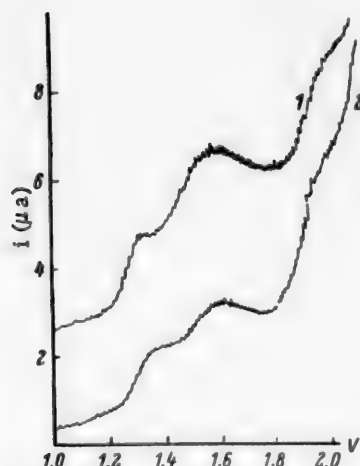
Fig. 3. Reduction waves of "phthalazole":
1) In the presence of a 0.2 M solution of
$(C_2H_5)_4NI$;   2) in 0.5 N LiCl.

the concentration of alkali in the solution. With increasing alkali content in the polarographic solution an increase in the height of the wave occurs, but only up to a certain limit, after which a further increase in alkali concentration does not change the height (Fig. 5).

When chlorides, sulfates and other salts are introduced into alkaline solutions, the diffusion current of "disulformin" decreases, while the half-wave potential is displaced in a positive direction. Thus, for example, in the presence of a 0.5 N solution of sodium hydroxide the current is equal to 6.6 μa, with a half wave potential of —1.7 v, while in the presence of 0.5 N lithium chloride and 0.03 N alkali the current is equal to 1.76 μa, with a potential of—1.56 v.

DISCUSSION OF RESULTS

The experimental data presented show that the sulfonamide compounds: "sulzimide," "urosulfane," "ethazole," "sulfodimesine," "phthalazole" and "disulformin" are related to the group of compounds which are reduced at the dropping mercury cathode.

Experimental data showing the dependence of the magnitude of the limiting current on the square root of the height of the mercury column show that the waves of "sulzimide," "sulfodimesidine," "urosulfane," "ethazole" and "phthalazole" have a diffusional character.

The limiting current of "disulformin" does not have a diffusional character since on reduction of the compound the current does not change with changes in the square root of the height of the mercury column. The dependence of the limiting current of "disulformin" on the concentration of alkali, and also the constancy of the polarographic waves in the time during electrolysis indicate the presence of kinetic processes which slow down reduction. The low magnitude of the diffusion coefficient of "disulformin," which was found from polarographic data— — of the order of 10^{-7}-10^{-8} cm^2/ sec—,is probably also due to kinetic hindrances during reduction (Table 4).

Our measurements indicate that the second wave of "ethazole" in some solvents is not related to diffusional limitations, but is apparently caused by the catalytic action of "ethazole" on the reduction of hydrogen. Insofar as the second wave does not increase during electrolysis and the accumulation of the reduction products of "ethazole" during the reaction at the electrode, one may assume that this catalysis is not related to the reaction products at the electrode.

"Phthalazole", which is a product of the combination of an amino group of sulfathiazole with phthalic acid, forms several waves on the polarographic curve depending on the reduction conditions. The reduction waves of "phthalazole" at potentials of—1.32 and —1.54 v, are probably related to the reduction of derivatives of phthalic acid [3, 4], while the half-wave potential—1.93 v—is related to the reduction of derivatives of sulfathiazole [1]. The first two waves are caused by the electrode reaction, for which n = 2, and for the third n = 1.

The reduction of "urosulfane" is very reminiscent of the polarographic behavior of albucid ,which was described previously [1]. In contrast to the methyl group that is present in the albucid molecule, the molecule contains

Fig. 4. Dependence of i_d on the value of pH for "phthalazole."

Fig. 5. Dependence of i_{lim} of "disul-formin" on the concentration of NaOH (N). Concentration of "disul-formin": $1 \cdot 10^{-2}$ M; background 0.5 N LiCl.

TABLE 4. Values of the Diffusion Coefficients of Sulfonamides in a Solution of 0.5 N Lithium Chloride in the Presence of 40% Alcohol

Compound	$D \, (cm^2/sec^{-1})$
Urosulfane	$0.18 \cdot 10^{-5}$
Sulfodimesine	$0.22 \cdot 10^{-5}$
Sulzimide	$0.17 \cdot 10^{-5}$
Disulformin	$0.91 \cdot 10^{-7}$
Phthalazole	$0.14 \cdot 10^{-5}$
Ethazole	$0.55 \cdot 10^{-6}$

an amino group. This substitution does not alter the character of the reduction, but it somewhat lowers the half-wave reduction potential. In the presence of a methyl group, reduction takes place at -2.16 v, while in the presence of an amino group it takes place as low as $-1.6 - 1.7$ v. Coinciding diffusion coefficients for albucid and "urosulfane," calculated from polarographic data, apparently also confirm the assumption of a similar reduction mechanism. Coulombmetric measurements of the number of electrons participating in the electrode reaction show that this number is one for "sulzimide," "urosulfane" and for the first diffusion wave of "ethazole."

Taking into consideration the possible displacement of electron densities in the molecules of the compounds mentioned, one may assume that as a result of their reduction, free radicals and hydrogen atoms are formed according to the following scheme:

$$H_2N\langle\rangle SO_2-\overset{H}{\underset{|}{N}}-CN + e \rightarrow H_2N\langle\rangle SO_2-\dot{N}-CN$$
$$(I)$$

$$H_2N\langle\rangle SO_2-\overset{H}{\underset{|}{N}}-CONH_2 + e \rightarrow H_2N\langle\rangle SO_2-\dot{N}-CONH_2$$
$$(II)$$

$$H_2N\langle\rangle SO_2-\overset{H}{\underset{|}{N}}-\overset{N-N}{\underset{S}{C}} C-C_2H_5 + e \rightarrow H_2N\langle\rangle SO_2-\dot{N}-\overset{N-N}{\underset{S}{C}} C-C_2H_5$$
$$(IV)$$
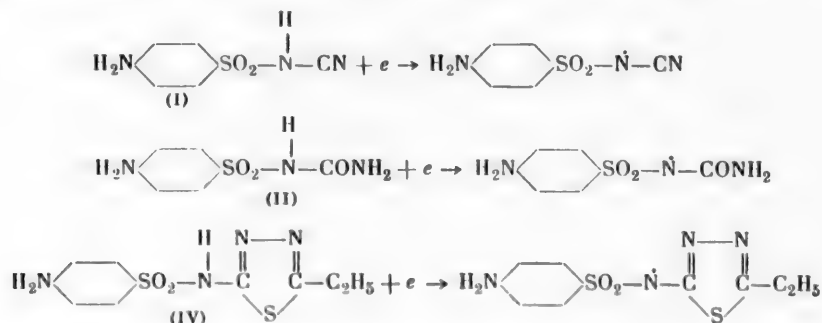
In the electrode reduction of "sulfodimesine," hydrogen ions take part, since the magnitude of the half-wave potential in this case is dependent on the concentration of hydrogen ions.

Comparison of the half-wave potentials of pyrimidine [2] with the reduction potentials of "sulfodimesine"found by us permits the assumption that the limiting currents of the latter are caused by the reduction of the dimethyl-pyrimidine group of atoms.

Thus, the reduction of sulfonamides takes place in various ways depending on the chemical nature of the substance, on the presence in the molecules of the compounds of polarographically active groups, and on the composition of the of the indifferent electrolyte.

SUMMARY

1. The polarographic behavior of a series of sulfonamide compounds—"sulzimide," "usosulfane," "sulgin," "ethazole," "sulfodimesine," "phthalazole" and "disulformin" during their reduction at a dropping mercury cathode was studied.

2. It was shown that the reduction of these compounds takes place in various ways depending on their chemical nature, on the presence of polarographically active groups, and on the composition of the background.

3. Hypotheses on the reduction mechanism of these compounds at the dropping mercury cathode were stated.

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POLAROGRAPHIC REDUCTION OF TRIETHYLLEAD HYDROXIDE

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The reduction of organo-lead compounds at a dropping mercury cathode has been studied by a number of authors [1-4].

In a paper by M. K. Saikina [3] the behavior of a large group of organohalogen compounds of lead was described in great detail. The author found that triethyllead chloride, tri-n-propyllead chloride and tri-n-butyllead chloride, on being reduced at a dropping mercury cathode, show diffusion waves on polarograms which are greatly distorted by large maxima which, the author concludes, are not suppressed and which make it difficult to get a reliable determination of the potentials of the half-waves of reduction.

The polarographic behavior of organo-lead hydroxides has not been described in the literature.

The present paper gives the results of studies of the rediction of triethyllead hydroxide under various conditions.

EXPERIMENTAL

The polarization curves were taken by means of a TsLA polarograph [5]. For the dropping mercury electrode a capillary was used, the dropping rate of which was 1.1 sec., and the weight of the mercury flowing per second into a solution of 0.4 N lithium chloride (with a potential at the drop of 0.72 v) was 2.27 mg. The comparison electrode was saturated calomel.

The original solution was prepared by dissolving triethyllead hydroxide,* which had been recrystallized from benzene, in water. The concentration of the original fresh solution of $(C_2H_5)_3PbOH$ was 0.004 M.

The polarographs were made in solutions of neutral salts, alkaline solutions and acetate-phosphate buffer solutions, prepared according to Britton-Robinson, with pH from 1.86 to 11.58, and in acetic acid-ammonia solutions with pH from 3.0 to 11.1. An LP-5 pH meter was used for determining the pH.

In all the solutions studied it was found that reduction of triethyllead hydroxide took place with the formation of two waves. Both waves were severely distorted by maxima, and a precise determination of the potentials of the half-waves was difficult.

On introducing gelatin into the polarographic solutions in a concentration of the order of 0.02%, and with a concentration of triethyllead hydroxide of less than 10^{-8} M, the maximum of the first wave is completely suppressed; the diffusion wave has the correct form, reproduces well, and may be used for the determination of the potential of the half-wave. If more concentrated solutions of triethyllead hydroxide are used, for example $3 \cdot 10^{-3}$ M, then the suppression of the maxima of the first diffusion wave ordinarily used for this purpose with surface-active substances does not take place. In this connection the behavior of triethyllead hydroxide on reduction at a dropping mercury cathode is similar to the behavior of triethyllead chloride, described by M. K. Saikina [3], who mentioned the presence of unsupressable maxima at concentrations of $(C_2H_5)_3PbCl$ of the order of 10^{-3} M.

In regard to the second reduction wave of triethyllead hydroxide at concentrations of 10^{-4} M in the polarographic solution, complete suppression of the maximum in this case has been impossible to achieve. Even when comparatively large amounts of gelatin are added, the maximum of the second wave is still considerable, and precise determination of the potential of the half-wave of the second stage of reduction remains difficult.

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* The sample was kindly supplied by the Kinetics Laboratory of our Institute.

TABLE 1. Half-wave Potentials and Diffusion Currents of Triethyl-
lead Hydroxide ($c = 6.4 \cdot 10^{-4}$ M)

pH	First wave		Second wave	
	i_d(µA)	$E_{1/2}$ (V)	i_d (µA)	$E_{1/2}$ (V)
Britton-Robinson buffer solutions				
1 86	1.52	−0.73	—	—
2.64	1.50	−0.72	—	—
3.77	1.51	−0.72	—	—
5.32	1.49	−0.72	—	—
6.21	1.51	−0.73	—	—
7.58	1.55	−0.73	1.90	−1.47
9.54	1.50	−0.75	1.11	−1.51
10.20	1.50	−0.76	0.90	−1.51
11.58	1.52	−0.87	0.61	−1.55
Acetic acid-ammonia buffer solutions				
3.0	1.60	−0.72	—	—
5.0	1.58	−0.70	—	—
7 7	1.58	−0.71	1.10	−1.53
9.3	1.58	−0.70	0.75	−1.50
11.1	1.60	−0.76	0.41	−1.46
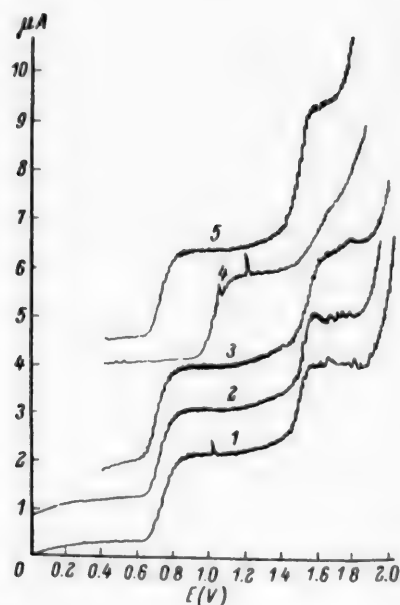
Fig. 1. Reduction waves of triethyllead
hydroxide ($c_{Et_3PbOH} = 6.4 \cdot 10^{-5}$ M). Back-
ground: 1) 0.2 N LiCl; 2) 0.2 N LiNO$_3$;
3) $(C_2H_5)_4$NI; 4) 0.5 N KOH, 5) buffer
solution pH 7.04.

Figure 1 shows the reduction waves of triethyllead hydroxide
against a background of various electrolytes. Tables 1 and 2 show the
potentials of the half-waves and the magnitudes of the diffusion currents
for triethyllead hydroxide in the presence of two component buffer solu-
tions and in solutions of some salts and alkalies.

In solutions with an acid reaction, one can observe only one re-
duction wave on the polarization curves, since the second wave fades
into the hydrogen wave of the background.

The following equation is true for the potential of the mercury
drop for the first diffusion wave at low concentrations of triethyllead
hydroxide in the presence of small quantities of gelatin.

$$E = E_{1/2} - \frac{RT}{nF} \ln \frac{i}{i_d - i} .$$

If the experimental data are plotted on the coordinates E-log

$E - \log \frac{i}{i_d - i}$ they coincide very satisfactorily with straight lines. By

using graphic methods, one can sufficiently accurately determine the
half-wave reduction potential of triethyllead hydroxide in the presence
of various electrolytes. The potentials of the half-waves may also be
found directly from the polarograms, and both methods give results that
coincide.

From the data shown in Tables 1 and 2 it can be seen that the
potential of the half-waves of the first reduction wave of triethyllead
hydroxide in all the solutions studied differs from the reduction poten-
tial of simple hydrated lead ion [6]. In buffer solutions with a pH of
less than 9.5, and also in solutions of neutral salts, the half-wave potential of the first stage of reduction is not de-
pendent on the concentration of hydrogen ions in the solution. Consequently the reduction of the hydroxide takes
place without the participation of hydrogen ions.
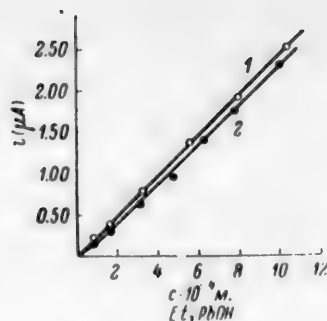
Fig. 2. Dependence of the diffusion current on the concentration of triethyllead hydroxide. 1) In a buffer solution of pH 7.04; 2) in an 0.8 N solution of KOH.
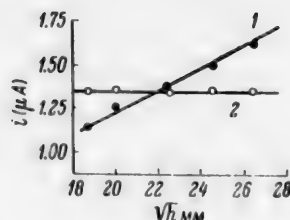
Fig. 3. Dependence of the diffussion current on the square root of the height of the mercury column. 1) For the first wave, 2) for the second wave of triethyllead hydroxide.

TABLE 2. Half-wave Potentials and Diffusion Currents of Triethyllead Hydroxide (c = 6.27 · 10^{-4} M)

Background	First wave		Second wave	
	i_d (μA)	$E_{1/_2}$ (V)	i_d (μA)	$E_{1/_2}$ (V)
0.2 N. LiCl	1.74	−0.74	1.52	−1.50
0.2 N. LiNO$_3$	1.79	−0.72	1.37	−1.53
0.02 N (C$_2$H$_5$)$_4$NI	1.86	−0.72	1.80	−1.56
0.5 N KOH	1.70	−1.02	1.20	−1.61

On reduction in strongly alkaline solutions, some shifting of the half-wave potential of the first stage of reduction in a negative direction may be observed. It is possible that this shifting of the reduction potential is caused by a decrease in the degree of dissociation of triethyllead hydroxide in strongly alkaline solutions.

A linear relationship is observed between the diffusion current of the first reduction wave and the concentration of triethyllead hydroxide against a background of various electrolytes (Fig. 2). For concentrations of triethyllead hydroxide within the limits of from $0.8 \cdot 10^{-4}$ to $10.4 \cdot 10^{-4}$ M, the diffusion current may be found from the equation $i_d = 2.4 \cdot 10^3$ c, where c is the molar concentration of triethyllead hydroxide in the solution.

By substituting in Il'kovich's equation the magnitudes t and m for the capillary used, it is possible to find the value of the diffusion coefficient of the reducing ions. Assuming that the reduction process at the mercury electrode takes place with the expenditure of one electron, the coefficient of diffusion, according to our calculations, is equal to $0.5 \cdot 10^{-5}$ cm^2 · sec^{-1}.

The limiting current of the second reduction wave of triethyllead hydroxide varies irregularly with changes in its concentration. For differing concentrations of triethyllead hydroxide the ratio of the height of the first wave to the height of the second wave likewise varies. The magnitude of this ratio also depends on the pH of the solution. It should be mentioned that the height of the second wave decreases greatly with an increase in the alkalinity of the background solution.

The diffusion current of the first reduction wave is proportional to the square root of the height of the column of mercury above the dropping electrode, which gives evidence of the diffusional character of the limiting current of the first wave (Fig. 3). No such dependence is observed in the case of the second wave. In our experiments the height of the mercury column was increased 2.5 times, but the height of the second wave remained practically unchanged. Therefore the second wave observed in the reduction of triethyllead hydroxide may not be considered to be a diffusional one.

The angular coefficient of the slope of the straight line for the first wave in $E - \log \frac{i}{i_d - i}$ coordinates against a background of buffer solutions, varies within the limits of 0.068 to 0.075. When an alkaline solution is used as background, the value is 0.077. These figures are close to the theoretical values for a one-electrode reduction process. The angular coefficient for the second wave is considerably larger; in the case of an alkaline solution, for example, it is equal to 0.14, which indicates the irreversibility of the process.

The reduction of triethyllead hydroxide in solutions of potassium hydroxide proceeds in a somewhat peculiar manner. At low concentrations of alkali— of the order of 0.05-0.1 N— the half-wave potential of the first wave is about− 0.9 v; on increasing the concentration of alkali it is displaced in a negative direction, and in the concentration range of the background of from 0.5 to 1.6 N, the value of the half-wave potential remains constant and is equal to −1.02 v. The magnitude of the half-wave potential changes somewhat with changes in the concentration of triethyllead itself, gradually shifting in a positive direction from −1.08 v to −1.02 v with an increase in the concentration of the hydroxide from $0.78 \cdot 10^{-4}$ to $7.8 \cdot 10^{-4}$ M. The magnitude of the diffusion current of the first wave does not vary with changes in the concentration of potassium hydroxide. The second wave, with low concentrations of alkali, divides into two waves lying at the potentials of the half-wave— about −1.37 and −1.56 v; with an increase in the concentration of KOH they come closer together, the bifurcation of the wave also becomes less noticeable, while in solutions with a 1.0-1.6 N concentration of KOH, in addition to the first diffusion wave, a second wave is observed at $E_{1/2} - 1.65$ v.

In order to determine the number of electrons participating in the reduction of triethyllead hydroxide at the mercury cathode, coulomb measurements were made in the apparatus described in a paper by V. N. Dmitrieva and V. D. Bezuglyi [7]. The measurements were carried out at a potential corresponding to the limiting current of the first wave, in a buffer solution with pH 7.58. As a result of these measurements it was found that the average value of a series of determinations was 0.98. With the passage of time and electrolytic action, the height of both the first and second waves decreases.

An analogous phenomenon is observed in the case of the potential of the limiting current of the second wave. The height of the second wave also decreases.

On the basis of the experiments that have been carried out it is possible to conclude that in the reduction of triethyllead hydroxide in buffer solutions and in solutions of other indifferent electrolytes, the first diffusion wave corresponds to the one electron reduction of the $(C_2H_5)_3Pb^+$ ion to a free radical, which further dimerizes.

$$(C_2H_5)_3Pb^+ + e \rightarrow (C_2H_5)_3Pb^\cdot$$
$$2\,(C_2H_5)_3Pb^\cdot \rightarrow (C_2H_5)_3Pb-Pb(C_2H_5)_3$$
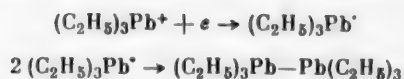
The dimer formed— hexaethyldilead is not stable in aqueous solutions and hydrolyzes. The second wave which is observed corresponds to the reduction of the nonhydrolyzed part of the dimer, which appears during the course of the reaction at the electrode.

As was shown by one of us, together with L. N. Bertyulina [4], the diffusion waves of hexaethyldilead may only be obtained by the reduction of this compound at a dropping mercury cathode in nonaqueous solutions.

SUMMARY

1. The polarographic behavior of triethyllead hydroxide in buffer solutions in a broad range of hydrogen ion concentrations in solutions of neutral salts and alkalies was studied.

2. It was suggested that the reduction of triethyllead hydroxide at a dropping mercury cathode proceeds through the formation of the free radical $(C_2H_5)_3Pb$.

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All abbreviations of periodicals in the above bibliography are letter-by-letter transliterations of the abbreviations as given in the original Russian journal. *Some or all of this periodical literature may well be available in English translation.* A complete list of the cover-to-cover English translations appears at the back of this issue.

THE DETACHMENT OF HYDRIDE HYDROGEN
FROM ORGANIC COMPOUNDS BY MEANS OF AZOBENZENE

A. N. Nesmeyanov and R. V. Golovnya

We have studied the behavior of phenyldiazonium borofluorides in ketones in an effort to explain the specifically favorable role of acetone in the reaction for producing onium [1] and organometallic compounds [2a] by the diazo method. It appears that along with decomposition with the separation of nitrogen in some ketones, cyclohexanone for example, intramolecular condensation like that of the Fischer reaction takes place. Cyclohexanone is converted into tetrahydrocarbazole. Apparently diazo compounds are intermediately converted into arylhydrazine; the hydrogen donor can only be this same ketone.

By using the unusual reaction of reducing two atoms of nitrogen joined to azobenzene in the presence of boron trifluoride as a catalyst in the case of cyclohexanone we also obtained tetrahydrocarbazole. In this case, instead of the separation of ammonia in the usual Fischer synthesis, aniline was detached. We have reported on this reaction individually [2b].

If in the reaction of azobenzene with cyclohexanone sulfuric acid is used instead of boron trifluoride the azobenzene, on being reduced, rearranges to form benzidine. The reduction of azobenzene and the benzidine rearrangement in the presence of sulfuric acid takes place, as we subsequently determined, not only in ketones, but also in almost all organic solvents. Even in the case of such oxidation-resistant compounds as nitrobenzene, benzene, cyclohexane, and n-hexane, azobenzene takes off a hydrogen and rearranges into benzidine. The reaction also takes place with thiophene, acetone, dibutyl ether, acetic, succinic* and formic acids, benzaldehyde, cycloheptatriene and benzyl alcohol. In the case of the last four compounds the reaction products are benzidine with an admixture of diphenyl and of dehydrogenation products of organic compounds—carbon dioxide, benzoic acid, tropyl cation and benzaldehyde.

In the case of all other organic solvents which also form benzidine with azobenzene under these conditions, they themselves are converted into tar—a black, infusible, finely dispersed powder containing carbon (54-65%), hydrogen (3-4%), nitrogen (3-9%), sulfur (2-3% and in the case of thiophene 21%), and an ash of sodium sulfate (0.5-11%). The time and the necessary reaction temperature vary within broad limits depending on the nature of the hydrogen donor. The yield of benzidine together with diphenylene varies from 7% in cyclohexane to 87% in benzaldehyde,based on the amount of azobenzene that reacted. We determined the optimum molar ratio of azobenzene and sulfuric acid (1 : 2) in the reaction with formic acid by measuring the quantity of carbon dioxide given off. A mixture of azobenzene with concentrated sulfuric acid (molar ratio 1 : 2) in the absence of an organic solvent does not react on heating on a water bath, nor does it on boiling in carbon tetrachloride. The reduction of abobenzene and the benzidine rearrangement also takes place if pyrophosphoric or borohydrofluoric acids are used in place of sulfuric acid. With pyrophosphoric acid the yield of benzidine in the reaction with dibutyl ether falls from 77% with sulfuric to 29%, while formic acid does not react at all.

It is interesting that in the reaction of azobenzene with acetone,phenylisonitrile was found in addition to benzidine and diphenylene. A very small quantity of phenylisonitrile is also obtained when azobenzene reacts with boiling acetic acid. This is some new sort of rearrangement, the nature of which still remains to be explained. The fact that azobenzene, zinc chloride and acetone on boiling form a significant amount of benzidine has been mentioned in a paper [3].

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* In the case of succinic acid the reaction was carried out in nitromethane, which does not react with azobenzene under these conditions.

When azobenzene in a current of nitrogen reacts with benzaldehyde, which does not contain benzoic acid, it is possible to avoid the formation of tar, and dibenzylidenebenzidine, benzidine and benzoic acid are formed. The formation of dibenzylidenebenzidine from benzaldehyde and azobenzene has been mentioned previously [4,5], but no other products of the reaction were separated.

The starting ability of azobenzene to detach hydrogen from such stable compounds as benzene, nitrobenzene, cyclohexane, n-hexane, and, on the other hand, the absence of a reaction with chloroform and nitromethane,which have a mobile (easily protonizing) hydrogen, allows us to propose the following reaction mechanism for the reduction of azobenzene: The electrophilic reagent (H_2SO_4, HCl, HBr, $ZnCl_2$, H_3PO_4, HBF_4) forms a salt with azobenzene* $[C_6H_5-\underset{\underset{H}{\vdots}}{N}=N-C_6H_5]^+ HSO_4^-$. The cation formed takes a hydrogen with a pair of electrons (hydride hydrogen) from

organic compounds, forming hydrazobenzene, which in turn is rearranged into benzidine.

$$\left[C_6H_5N=NC_6H_5 \cdot HSO_4^- \atop \underset{H}{\vdots} \right] + \text{II:) } C \!\!<\;\; \to\; C_6H_5NH-NHC_6H_5 + \;>\!C + HSO_4^-$$
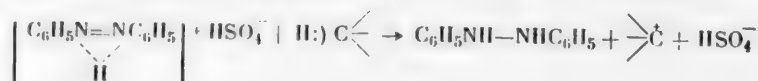
The resulting carboxy cation from the organic donor of the hydride ion apparently becomes stable in the majority of cases after having given up a proton with the formation of a multiple bond. The unsaturated compound further polymerizes in the presence of sulfuric acid. In almost all cases we obtain a tar, in which analysis shows that the quantity of carbon atoms approximately corresponds with the quantity of hydrogen atoms and for oxygen approximates from 30-34%. The considerable nitrogen content of the tars (up to 9%) may be explained both by the formation of alkylbenzidines

$$NH_2C_6H_4C_6H_4NH_2 + \overset{+}{C}\!\!< \;\to\; NH_2C_6H_4C_6H_4NHC\!\!< + H^+,$$
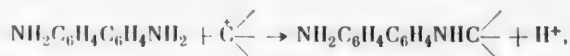
and by the ion exchange properties of the tar which is able to hold benzidine firmly.

Evidence for the reaction mechanism we have proposed is the special ease of reaction of azobenzene at room temperature with tropylidenyl- and benzyl alcohol, which, as is well-known, easily give up hydride hydrogen [7]. Tropylidene** in this case forms a salt of tropyllium, while benzyl alcohol forms benzaldehyde.

The formation of benzoic acid and carbon dioxide in the reaction of azobenzene with benzaldehyde and formic acid, respectively, also gives evidence of the reduction of azobenzene by hydride hydrogen [8].

A considerable amount of data in the literature on the reduction of azobenzene in halogen acids contradicts the reaction mechanism that we have proposed. The conversion of azobenzene to benzidine by the action of fuming hydrochloric acid at 100°, and also on boiling in dilute sulfuric acid was first noted by N. N. Zininyi [9, 10]. The reaction was carried out in ampoules. Later it was shown [11] that the reaction also proceeds on boiling with hydrobromic acid. M. M. Tikhvinskii [12] and later Jacobson [13] studied the mechanism of the reaction discovered by N. N. Zininyi. Tikhvinskii carried out the reaction in glacial acetic acid at 100°, passing a current of dry hydrogen chloride or hydrogen bromide through it. In addition to benzidine they separated 4-bromo- and 2-bromoaniline and 2,4-dibromoaniline, and in the experiment with hydrogen chloride they obtained 4-chloro- and 2-chloroaniline and 2,4-dichloroaniline. The same results were obtained by Jacobson, who carried out the reaction in methyl alcohol saturated with hydrogen chloride. Among reaction products tetrahalogen-4-aminodiphenylamine was found along with benzidine and halogenanilines. It was suggested that the reaction goes as follows:

$$C_6H_5-N=N-C_6H_5 + 2HCl \to Cl_2 + C_6H_5NH-NHC_6H_5$$

$$C_6H_5-N=N-C_6H_5 + 4HCl \to o\text{-}ClC_6H_4NH_3Cl + p\text{-}ClC_6H_4NH_3Cl.$$
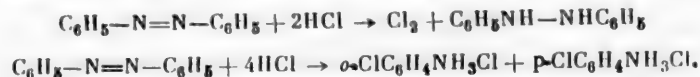
We investigated whether on boiling azobenzene with halogen acids the reaction proceeds otherwise than in the above-described reactions with organic donors of hydride ion. Azobenzene reacts completely on boiling in 40% hydrobromic acid for three hours. From the reaction products we separated benzidine and bromobenzidine containing an admixture of dibromobenzidine and traces of n-bromoaniline, which was determined chromatographically.

* Analogous salts of azobenzene and hydrochloric acid were separated and studied by Jaffe [6].
** We take this occasion to express our sincere thanks to M. E. Vol'pin for supplying the tropylidene.

On boiling azobenzene in concentrated hydrochloric acid, part of the azobenzene (49%) reacts and forms benzidine, chlorobenzidine and dichlorobenzidine. The formation of dihalogenoanilines was not observed with either hydrochloric or hydrobromic acids although we used the method of separation described by Tikhvinskii; their absence was shown by paper chromatography [14].

It is apparent that even in aqueous solutions of halogen acid salts   azobenzene removes a hydride ion, just as it does with organic substances, while the remaining positive halogen ion halogenates benzidine. Thus, the salts of azobenzene with strong acids are very strong hydride ion acceptors—stronger than the cation. The removal of the hydride ion from benzene, thiophene and other aromatic compounds is especially interesting. One may suspect the formation of Wittig's dehydrobenzene and its analogs,which polymerize to tar in the presence of sulfuric acid. We are studying this aspect of the problem at the present time.

EXPERIMENTAL

Reaction with formic acid. A mixture of 6 g (0.0329 M) of azobenzene, 7 g (0.066 M) of sulfuric acid in 50 ml of 100% formic acid was boiled for ten hours. The carbon dioxide given off was absorbed in 100 ml of a 10% solution of barium hydroxide. The weight of barium carbonate was 2.5 g (0.0126 M). On the completion of the reaction formic acid was mixed with the residue in the bottom of the flask, water was added to make a volume of 200 ml, the solution was made alkaline, and azobenzene and amines were extracted by means of ether and chloroform. The residue in the reaction vessel was also made alkaline and the suspension was extracted with chloroform. By means of paper chromatography it was shown [14] that the combined ether-chloroform extracts contain azobenzene, benzidine and traces of diphenylene. Benzidine and diphenylene were separated by washing with 5% hydrochloric acid. Benzidine was precipitated from the hydrochloric acid solution as its hydrochloride salt. The yield was 2.65 g (0.0094 M, 74.6% based on the amount of azobenzene that entered the reaction). 0.5 g of benzidine sulfate were converted into benzidine,which crystallized from aqueous alcohol; m.p. 122°. From the ether-chloroform extract, 3.7 g of unreacted azobenzene was obtained. When the reaction was carried out with formic acid under the same conditions, but with 3.5 g of concentrated sulfuric acid, the yields of barium carbonate and benzidine were reduced by half.

Reaction with dibutyl ether. 100 ml of dibutyl ether containing 20 g (1.109 M) of azobenzene and 12.5 ml of concentrated sulfuric acid (d 1.84) were heated for four hours with a reflux condenser at 100°. A black tar-like deposit was formed on the bottom of the flask. Dibutyl ether was poured from the deposit and the residue washed several times with boiling ether. The ether extracts were combined with the dibutyl ether. 2.9 g of azobenzene were recovered from the dibutyl ether after washing it with dilute hydrochloric acid to free it from amines. The deposit in the flask was made alkaline and centrifuged; the weight of the air-dry, amorphous powder was 20 g. The alkaline filtrate was extracted with chloroform and ether. From the ether-chloroform extracts,which were shown by chromatography to contain benzidine and diphenylene, 7.7 g (0.027 M) of benzidine sulfate and diphenylene in the form of dibenzoyldiphenylamine— 0.7 g (0.0033 M) were recovered; m.p. 276-278°; the literature [15] shows m.p.277-278°. One g of amorphous powder was heated with 40 ml of 10% alkali; after cooling the suspension was repeatedly extracted by centrifuging with chloroform. 0.42 g of benzidine were separated from the chloroform extracts, which corresponds to a general content of benzidine in the deposit of 8.5 g (0.046 M). The over-all yield of benzidine, calculated on the amount of azobenzene that reacted, was 77.2%.

The remaining black powder after the removal of the benzidine was washed free from alkali by 5% hydrochloric acid, and repeatedly washed with hot water, alcohol and ether. Weight 0.25 g.

Found %: C 65.96; H 4.74; S 2.29; N 9.41; ash 0.67.

0.2 g of this substance was flooded with 5% hydrochloric acid, diazotized with sodium nitrite, the deposit filtered off and, from the filtrate combined with β-naphthol, diphenyl-4,4'-di(azo-β-naphthol) was separated, decomposition temperature 273-275° (according to the literature this temperature is 273-275° [16]). The deposit, after washing with 5% alkali, hot water, alcohol and ether, was analyzed.

Found %: C 61.79; H 3.75; S 4.78; N 7.65; ash 0.57.

When the reaction is carried out in dibutyl ether under the same conditions, but using 10 g of pyrophosphoric acid instead of concentrated sulfuric acid, 18.3 g of azobenzene were recovered from the reaction. 0.5 g of benzidine were obtained (29% based on the amount of azobenzene entering the reaction). A black, amorphous powder was analyzed.

Found %: C 71.26; H 4.29; N 6.62; P 1.75.

Reaction with benzene. A mixture of 20 g of azobenzene, 12.5 ml of concentrated sulfuric acid in 100 ml of dry cryoscopic benzene was boiled under a reflux condenser for 10 hr. The organic layer and the deposit were worked up in the same way as in the experiment with dibutyl ether. 12.3 g (61%) of azobenzene, which did not react, and 0.46 g of benzidine with an admixture of diphenylene were obtained. The weight of the black amorphous powder was 12.65 g; 2 g of this powder were treated as in the preceding experiment. 0.74 g of benzidine was separated out, which corresponds to an over-all benzidine content in the amorphous powder of 4.68 g; consequently the total yield of benzidine in the reaction was 5.14 g (78.9%, based on the azobenzene reacting).

Reaction with thiophene. A mixture of 10 g of azobenzene, 6 ml of concentrated sulfuric acid and 40 ml of thiophene was boiled under a reflux condenser for two hours. The organic layer and the residue were worked up just as in the experiment with dibutyl ether. 4.4 g of azobenzene were recovered from the reaction and 12.85 g of a black, finely dispersed powder were obtained. From one g of this powder 0.33 g of benzidine was obtained, which corresponds to an over-all benzidine content in the black powder of 4.24 g (76% based on the azobenzene reacting). The black powder remaining after separation of the benzidine was washed with 5% hydrochloric acid, hot water, and then with alcohol and ether.

Found %: C 54.14; H 3.30; S 21.65; N 3.66; ash 9.55.

Reaction with n-hexane. A mixture of 10 g of azobenzene, 6 ml of concentrated sulfuric acid and 65 ml of n-hexane was boiled for 10 hr. The organic layer and the black tar-like residue in the flask were worked up just as in the experiment with dibutyl ether. 8.9 g of azobenzene and 0.25 g of benzidine which did not contain diphenylene were obtained. The yield of benzidine, calculated on the azobenzene that reacted, was 22%.

Reaction with cyclohexanone. The quantities of reagents and the reaction conditions were the same as in the preceding experiment. The organic layer and the black tarry residue in the flask were worked up just as in the experiment with dibutyl ether. 4.8 g of azobenzene were recovered from the reaction. 7.8 g of a black powder were obtained, the benzidine content of which was 0.39 g (7.5%, based on the azobenzene reacting). The material remaining after removing the benzidine from one g of the black powder was washed with 5% hydrochloric acid and repeatedly with hot water, alcohol and ether.

Found %: C 62.68; H 4.55; S 2.77; N 9.46; ash 1.62.

Reaction with nitrobenzene. The reaction was carried out in a current of nitrogen.[*] Reagents were used in the same ratio as in the experiment with n-hexane. The temperature of the reaction mixture was maintained at 140-150° for three hours. After cooling the reaction mixture in a current of nitrogen, the organic layer and the residue were worked up separately. From the nitrobenzene solution, washed free of amines and nitrobenzoylsulfonic acids, 0.5 g of unreacted azobenzene was recovered. The residue in the flask was made alkaline and filtered out. The weight of the dry black powder was 6.5 g. From the filtrate 3.79 g of hydrochloric and 0.42 g of sulfuric salts of benzidine were obtained. These salts, as shown by paper chromatography, only contained benzidine. The black powder (6.5 g) was washed with 50 ml of alcohol; 3.2 g of benzidine were obtained from the alcohol solution. Consequently the over-all yield of benzidine was 64.2% based on the azobenzene that reacted. One g of the black powder, washed as in the experiment with dibutyl ether, was analyzed.

Found %: C 55.04; H 4.27; N 9.13; ash 11.39.

Reaction with cyclohexanone. The ratio of reagents used was the same as in the experiment with n-hexane. The reaction mixture was heated on a boiling water bath for three hours. On the walls of the flask a layer of the white sulfuric salts of benzidine was observed, while on the bottom of the flask there was a black tarry residue. The organic layer was removed and washed free of amines with weak hydrochloric acid; the cyclohexanone was driven off with the aid of a water exhaust vacuum pump and the azobenzene was distilled in vacuo, b.p. 130-135° (5 mm); yield 2.1 g. The undistilled residue (3 g) was a black glassy mass. The deposit remaining in the reaction flask was dissolved in concentrated sulfuric acid, diluted three times with water, and the benzidine sulfate filtered off; yield 6 g (0.0212 M). Paper chromatography showed that the sulfuric acid salt only contained benzidine. From 0.5 g of this salt, neutralized with alkali, benzidine was separated; m.p. 121-122°. Diphenylene in the form of its dibenzoyl

[*] In all experiments nitrogen was used that had been freed from oxygen by passage over incandescent copper filings.

derivative 0.5 g (0.0012 M) was separated from the sulfuric acid solution after alkalization and extraction with ether, m.p. 276-278°; data from the literature [15] show m.p. 276-278°. The over-all yield of benzidine and diphenylene based on the azobenzene that reacted was 51.0%.

Reaction with acetone. Ten g of azobenzene, 6 ml of concentrated sulfuric acid and 80 ml of anhydrous acetone were boiled for one hour with stirring in a current of nitrogen. Subsequently the acetone was driven off on a water bath; the residue in the flask was repeatedly washed with ether to free it from unreacted azobenzene, then it was made alkaline and the suspension was subjected to steam distillation. The distillate had a strong smell of isonitrile, and a qualitative test for aniline was positive. The suspension that did not distill with steam was filtered. The residue was treated by boiling with methyl alcohol, and from the methyl alcohol (200 ml) 2 g of a sulfuric acid salt of benzidine were obtained. Then the residue was repeatedly washed with boiling ether and chloroform. Another 2.0 g of benzidine containing an admixture of diphenylene were obtained from the ether-chloroform extracts. The over-all yield of benzidine was 39.5% based on the azobenzene that reacted. The weight of the remaining black powder was 1.6 g. 1.65 g of azobenzene were recovered from the reaction.

Reaction with benzaldehyde. The quantity of reagents was the same as in the n-hexane experiment. The reaction mixture was boiled for 30 min. The benzaldehyde was poured off and the residue in the flask washed several times with ether, and the ether combined with the benzaldehyde. The benzaldehyde was driven off in vacuo and there remained 1.6 g of azobenzene. The residue in the flask was worked up as described in the experiment with dibutyl ether. 11.36 g of a black powder were obtained. From one g of the powder after treatment with hot alkali and subsequent extraction with chloroform and ether, 0.6 g of benzidine with an admixture of diphenylene was obtained; the over-all yield was 6.8 g (80.9% based on the amount of azobenzene that reacted).

Reaction with benzaldehyde in a current of nitrogen. The quantity of reagents and the reaction time were the same as in the preceding experiment. The freshly distilled benzaldehyde that was used was carefully washed free from benzoic acid with sodium bicarbonate. The reaction was carried out in a current of nitrogen. On completion of the reaction the benzaldehyde was poured off. Water was poured over the light-yellow precipitate of dibenzylidenebenzidine, the suspension was extracted with ether, and the ether was combined with the benzaldehyde. From the ether-benzaldehyde layer, washed with a solution of sodium bicarbonate, 6.1 g of azobenzene were recovered. 1.25 g (0.0102 M) of benzoic acid, m.p. 119-121°, were recovered from the sodium bicarbonate solution. Then the dibenzylidenebenzidine was filtered off. It crystallizes from dichloroethane as small white needles with m.p. 238-239°. The literature shows m.p. 238° [5]. The yield was 2.5 g (0.0069 M); 64.1% based on the azobenzene that reacted). From the filtrate after alkalizing and extracting with chloroform, 0.1 g of benzidine was obtained.

Reaction with succinic acid. A mixture of 10 g of azobenzene, 6 ml of concentrated sulfuric acid, 7 g of succinic acid and 70 ml of nitromethane was boiled with continuous stirring in a current of nitrogen for six hours. On working up the reaction mixture 9 g of azobenzene, 5.5 g of succinic acid and 0.5 g of benzidine were obtained; diphenylene could be detected only by chromatography.

Reaction with acetic acid. A mixture of 10 g of azobenzene, 6 ml of concentrated sulfuric acid and 50 ml of acetic acid was boiled for 1.5 hr without visible change; then suddenly the reaction went very vigorously and gave off heat. The heating was stopped, and after cooling, the reaction mixture was diluted with water and filtered. Azobenzene which was contained in the residue was removed with boiling ether and 4.4 g of it were recovered. Then the residue was treated with 10% alkali, the suspension cooled and filtered, the filtrate extracted with chloroform, and the residue repeatedly washed with boiling ether. The weight of the remaining black powder was 1.5 g. The solvent was driven off from the combined ether-chloroform extracts and the residue steam-distilled. The distillate contained phenylisonitrile, and aniline, which was identified as N-benzoylaniline, m.p. 160°. From the remainder, which did not distill with steam, 0.6 g of benzidine was separated (10.7% based on the azobenzene that reacted). If the reaction mixture is heated on a boiling water bath for 10 hr, the yield of benzidine amounts to 0.25 g (35.7% based on the azobenzene reacting), and 9.3 g of azobenzene are recovered from the reaction. The reaction mixture does not contain aniline or phenylisonitrile.

Reaction with hydrobromic acid. A suspension of 10 g (0.0549 M) of azobenzene in 200 ml of 40% hydrobromic acid was boiled under a reflux condenser for three hours. All the azobenzene reacted. The white precipitate of hydrogen bromide salts of amines was filtered off and dissolved in water. From the aqueous solution and the filtrate which had been diluted threefold with water, sulfuric acid salts of benzidine and bromobenzidine were obtained. The yield of these salts was 8.54 g (0.0132 M). By means of chromatography on paper saturated with vaseline

oil [14], it was determined that the mixture contained benzidine and bromobenzidine; there were no bromine containing anilines. According to the analytical data the ratio of benzidine to bromobenzidine was almost 1 : 1.

Found %: C 45.26, 45.29; H 4.50, 4.40; N 9.32, 9.19; Br 11.96, 11.71. $C_{24}H_{27}O_8N_4S_2Br$. Calculated %: C 44.8; H 4.2; N 8.7; Br 12.4.

The filtrate, after removal of the sulfuric acid salts of benzidine and bromobenzidine, was made alkaline and extracted with chloroform. Half of the chloroform solution was washed with dilute sulfuric acid and the extract subjected to fractional distillation with steam according to Tikhvinskii's procedure [12]. Neither aniline nor dihalogen anilines were found in the distillate. 0.12 g of p-bromoaniline was obtained. The suspension which did not pass over with the steam was extracted with chloroform; from the chloroform extracts the picrates of bromobenzidine and diacetyldibromobenzidine were obtained. The picrate of bromobenzidine crystallizes from alcohol as yellow-brown needles, decomposition temperature 198-205°.

Found %: C 44.17, 44.20; H 3.01, 2.96; Br 15.54, 15.72; N 13.91, 14.01. $C_{18}H_{14}O_7N_5Br$. Calculated %: C 43.91; H 2.86; Br 16.23; N 14.22.

Diacetyldibromobenzidine crystallizes from alcohol as small white needles, m.p. 228-230°.

Found %: C. 45.26, 45.47; H 3.50, 3.50; Br 37.26, 37.20; N 6.56, 6.42. $C_{16}H_{14}O_2N_2Br_2$. Calculated %: C 45.07; H 3.28; Br 37.58; N 6.67.

From the remaining chloroform solution 4.06 g (0.0086 M) of dibenzylbromobenzidine were obtained by benzoylation by means of benzoyl chloride in the presence of dry potash; consequently the over-all yield of dibenzoylbromobenzidine was 31.3% based on the azobenzene that reacted. The dibenzoylbromobenzidine was recrystallized three times from xylol, decomposition temperature 249-252°.

Found %: C 66.66, 66.72; H 4.24, 4.31; Br 16.01, 16.11; N 5.83, 5.87. $C_{26}H_{19}O_2N_2Br$. Calculated %: C 66.25; H 4.06; Br 16.95; N 5.94.

Reaction with hydrochloric acid. The ratio of reagents used was the same as in the experiment with hydrobromic acid. The reaction mixture was boiled for three hours under a reflux condenser; then after cooling in an ice bath it was saturated with hydrogen chloride and heated for another three hours. The unreacted azobenzene was filtered off, repeatedly washed with warm water, and extracted with ether; 5.1 g of it were obtained. The wash waters were combined with the filtrate, the solution made alkaline and extracted with chloroform. The chloroform extracts were washed with 2% hydrochloric acid. Sulfuric acid salts of benzidine and chlorobenzidine were obtained from the hydrochloric acid solution by treatment with dilute sulfuric acid. The yield was 2.6 g. By means of paper chromatography it was shown that the salt contains benzidine and chlorobenzidine; there was no aniline nor chloroanilines. According to the analytical data, the salt contains about 37% of chlorobenzidine and 63% of benzidine.

Found %: C 48.54, 48.47; H 4.46, 4.66; Cl 4.17, 4.10; N 9.28, 9.27. Calculated %: C 48.8; H 4.59; Cl 4.13; N 9.8.

After separation of the sulfuric acid salts of benzidine and chlorobenzidine, the filtrate was made alkaline and extracted with chloroform. Half of the chloroform solution was benzoylated with benzoyl chloride in the presence of dry potash. 1.95 g of dibenzoylchlorobenzidine were obtained; it crystallized well from benzene, alcohol and xylol as white needles; m.p. 237-238°.

Found %: C 73.00, 73.07; H 4.76, 4.82; Cl 7.61, 7.55; N 6.45, 6.36. $C_{26}H_{19}O_2N_2Cl$. Calculated %: C 72.91; H 4.48; Cl 8.08; N 6.56.

The over-all yield of benzidine was 0.0057 moles (21.1%), and of chlorobenzidine 0.0098 moles (36.4% based on the azobenzene that reacted).

The amines in the remaining fraction of the chloroform solution were subjected to fractional distillation with steam according to Tikhvinskii's method; no aniline or dihalogenanilines were found. Traces of p-chloroaniline were observed.

Reaction with cycloheptatriene. A mixture of 0.9 g of azobenzene and 1.2 g of concentrated sulfuric acid was allowed to stand overnight in a closed flask. The solid salt of azobenzene which was formed was carefully pulverized and covered with 5 ml of dry nitromethane containing 0.5 g of cycloheptatriene. The suspension was

left at room temperature for 45 min. Within five minutes the material in the flask was converted into a viscous mass ,which from time to time was carefully triturated. Then the nitromethane was poured from the mass. It was washed several times with ether to free it from azobenzene. 0.3 g of azobenzene was recovered from the ether solution, which did not contain the tropylium cation. The benzidine sulfate remaining in the residue was carefully washed with warm water to free it from salts of tropolone. The tropylium cation was precipitated from the aqueous solution as tropolone chloroplatinate. Another 0.8 g of tropolone chloroplatinate was obtained from the nitromethane solution by the addition of an alcoholic solution of platino-hydrochloric acid. The yield of tropolone chloroplatinate, recrystallized from 5% hydrochloric acid, was 0.460 g (70% from benzidine based on the tropylium cation).

Found %: C 28.41, 28.55; H 2.48, 2.45; Cl 36.01, 35.86; Pt 33.07, 32.95. $C_{14}H_{14}C_{16}Pt$. Calculated %: C 28.48; H 2.39; Cl 36.04; Pt 33.07.

Benzidine sulfate was neutralized with 10% alkali and recrystallized from aqueous alcohol, m.p. 121-122°; yield— 0.420 g (70% based on the azobenzene that reacted).

Reaction with benzyl alcohol. 2.5 g of azobenzene and 3 g of concentrated sulfuric acid were carefully triturated and cooled, and then 25 ml of benzyl alcohol, distilled in vacuo, b.p. 80° (5 mm) were added. The mixture was shaken for six hours at room temperature and then 200 ml of ether were added. The benzidine sulfate that separated out was filtered off, washed with 75 ml of ether and dried. The yield was 1.8 g (47% based on the amount of azobenzene that reacted). After driving off part of the ether from the ether solution (which had been washed free of traces of diphenylene) benzaldehyde was separated out as the 2,4-dinitrophenylhydrazone, m.p. 239°.

Found %: C 54.26, 54.50; H 3.46, 3.58; N 19.40, 19.48. $C_{13}H_{10}O_4N_4$. Calculated %: C 54.36; H 3.49; N 19.45.

The over-all yield of benzaldehyde was 70.3% based on benzidine. If the reaction is carried out at 60-80°, the yield of benzidine sulfate is increased to 65% based on the azobenzene reacting.

SUMMARY

1. Azobenzene in the presence of sulfuric acid (molar ratio 1 : 2) removes a hydride anion from the majority of organic compounds (n-hexane, cyclohexane, cyclohexanone, acetone, benzaldehyde, formic, acetic and succinic acids, nitrobenzene, benzene, thiophene, dibutyl ether, benzyl alcohol, tropylidene), and also from hydrochloric and hydrobromic acids (without sulfuric acid), and undergoes the benzidine rearrangement.

In chloroform, nitromethane and carbon tetrachloride, i.e., without an organic donor of a hydride ion, azobenzene in the presence of sulfuric acid remains unchanged.

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δ-LACTONES AND δ-LACTAMS

XXIV.*. THE REDUCTION OF δ-ENOLLACTONES BY LITHIUM ALUMINIUM HYDRIDE. THE PREPARATION OF Δ²-DIHYDROPYRANS

N. P. Shusherina, I. S. Trubnikov and R. Ya. Levina

The only example of the reduction of enollactones by lithium aluminium hydride that has appeared in the literature is one of the γ-enollactones (angelicolactone). The product of the reaction was γ-acetylpropyl alcohol (yield 65%) [1].

Continuing our studies of the chemistry of lactones, we investigated the action of lithium aluminium hydride on δ-lactones (3,4-dihydropyrone-2). Lactones containing alkyl substituents in positions 5 and 6 [2-4] were reduced and it was found that on prolonged boiling with lithium aluminium hydride they form δ-ketoalcohols (I), which easily split off water and are converted into Δ²-dihydropyrans (II).

$$\underset{CH_3}{\overset{R}{\diagdown}} \diagup \overset{|}{CO} \xrightarrow{\text{LiAlH}_4} \underset{CH_3-CO \quad CH_2OH}{\overset{CH_2}{\overset{|}{R-CH \quad CH_2}}} \xrightarrow{-H_2O} \underset{CH_3}{\overset{R}{\diagdown}} \diagup \overset{|}{O}$$

(I)   (II)
R = H, CH₃, C₃H₇.
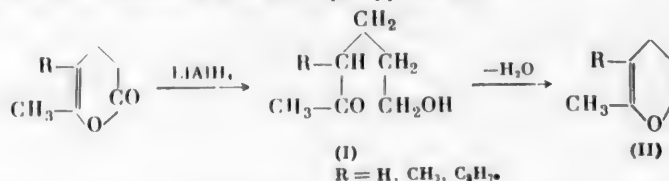
In this way we obtained Δ²-dihydropyrans with alkyl substituents in positions 2 and 3: 2-methyl-Δ²-dihydropyran (II, R = H; yield, 30%), 2,3-dimethyl-Δ²-dihydropyran (II, R = CH₃; yield 40%) and 2-methyl-3-propyl-Δ²-dihydropyran (II, R = C₃H₇; yield 45%).

The first of these dihydropyrans (2-methyl-Δ²-dihydropyran) was obtained previously by the decarboxylation of the corresponding Δ²-pyrancarboxylic acid [5]; the constants of our product coincided with those in the literature [5, 6].

Keto alcohols (I, R = H and C₃H₇), formed by the reduction of 6-methyl-3,4-dihydropyrone-2 and 6-methyl-5-propyl-3,4-dihydropyrone-2 could not be separated in pure form, since they were immediately converted into Δ²-dihydropyrans by dehydration.

The reduction product of 5,6-dimethyl-3,4-dihydropyrone-2 — γ-acetoamyl alcohol (I, R = CH₃) was separated in pure form; its structure was confirmed by independent synthesis from the nitrile of γ-acetylvaleric acid. The ethyl ester of this keto acid was obtained by the action of alcohol on the nitrile of γ-acetylvaleric acid in the presence of hydrogen chloride; then, in order to protect the keto group, it was converted into ethyleneketal. On the reduction of the latter by lithium aluminium hydride the ethyleneketal of γ-acetamyl alcohol was obtained, and from it — by removal of the protection — γ-acetoamyl alcohol was obtained.

$$\underset{CH_3COCHCH_2CH_2CN}{\overset{CH_3}{\overset{|}{}}} \xrightarrow[\text{HCl}]{C_2H_5OH} \underset{CH_3COCHCH_2CH_2CO_2C_2H_5}{\overset{CH_3}{\overset{|}{}}} \rightarrow$$

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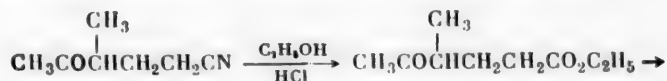
*For report XXIII, see DAN SSSR **135**, 1406 (1960).

$$\rightarrow CH_3CCHCH_2CH_2CO_2C_2H_5 \xrightarrow{LiAlH_4} CH_3CCHCH_2CH_2CH_2OH \xrightarrow{HCl}$$

with CH$_3$ substituents and O–O bridges as shown, yielding

$$\rightarrow CH_3COCHCH_2CH_2CH_2OH$$
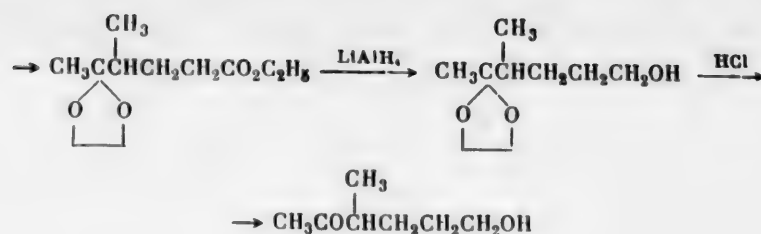
Both preparations of γ-acetoamyl alcohol were identical.

EXPERIMENTAL

$\underline{\Delta^2\text{-Dihydropyrans from }\delta\text{-enollactones.}}$ To a 0.04 M solution of δ-enollactone [2-4] in 100 ml of absolute ether was added 0.025 moles of lithium aluminium hydride. This was stirred and boiled for 24 hr; then 4 ml of methyl alcohol and 50 ml of 10% sulfuric acid were added and stirred until solution was completed. The ether layer was removed and the aqueous layer, after being saturated with sodium chloride, was repeatedly extracted with ether (up to 10 times). The combined ether solutions were dried over calcined potash for 24 hr and the ether was then driven off. The residue, which was a keto alcohol, immediately dehydrogenated to dihydropyran.

$\underline{\text{2-Methyl-}\Delta^2\text{-dihydropyran.}}$ From the reduction product of 6-methyl-3,4-dihydropyrone-2 the ether was driven off and the residue distilled in the presence of iodine. A fraction with b.p. 90-120° (750 mm) was collected. After removal of the water and drying over sodium sulfate, the reaction product was again distilled; yield 30%.

B.p. 108° (762 mm), $n^{20}D$ 1.4442, d^{20}_4 0.9046, MR$_D$ 28.88. $C_6H_{10}OF$. Calculated 28.88.

2,4-Dinitrophenylhydrazone melted at 99-101°. Data from the literature: b.p. 109° (757 mm), $n^{15}D$ 1.4485, d^{15}_{15} 0.9090 [5], d^{20}_4 0.9060 [6]; 2,4-dinitrophenylhydrazone: m.p. 96-97° [7].

$\underline{\text{2,3-Dimethyl-}\Delta^2\text{-dihydropyran.}}$ The reduction product of 5,6-dimethyl-3,4-dihydropyrone-2 was dehydrogenated as described above. The fraction distilling between 120-140° (760 mm) was worked up in the usual manner and redistilled. It has not been described in the literature; yield 40%.

B.p. 134-135° (752 mm), $n^{20}D$ 1.4541, d^{20}_4 0.9082, MR$_D$ 33.46. $C_7H_{12}OF$. Calculated 33.50.

Found %: C 74.99, 74.75; H 11.15, 11.17. $C_7H_{12}O$. Calculated %: C 74.95; H 10.79.

$\underline{\text{2-Methyl-3-propyl-}\Delta^2\text{-dihydropyran.}}$ The reduction product of 6-methyl-5-propyl-3,4-dihydropyrone-2 was slowly distilled in a vacuum and the fraction boiling between 90-95° (60 mm) was collected. After removing the water and drying the ether solution over sodium sulfate, it was repeatedly redistilled. Yield 45%; it is not described in the literature.

B.p. 55° (10 mm), 165° (760 mm), $n^{20}D$ 1.4575, d^{20}_4 0.8928, MR$_D$ 42.81. $C_9H_{16}OF$. Calculated: 42.71.

Found %: C 76.92, 77.02; H 11.58, 11.41. $C_9H_{16}O$. Calculated %: C 77.11; H 11.49.

γ-Acetoamyl alcohol (I, R = CH$_3$). The ether was evaporated from the ether solution of the reduction product of 5,6-dimethyl-3,4-dihydropyrone-2 and the remainder redistilled in vacuo. Yield 42%; it is not described in the literature.

B.p. 104-106° (10 mm), $n^{20}D$ 1.4483, d^{20}_4 0.9752, MR$_D$ 35.75. $C_7H_{14}O_2$. Calculated 36.06.

Found %: C 64.83, 64.68; H 10.76, 10.99. $C_7H_{14}O_2$. Calculated %: C 64.60, H 10.84.

It was not possible to obtain the semicarbazone and 2,4-dinitrophenylhydrazone of γ-acetoamyl alcohol by the usual methods.

$\underline{\text{Independent synthesis of }\gamma\text{-acetoamyl alcohol. The ethyl ester of }\gamma\text{-acetovaleric acid.}}$ To 30 ml of anhydrous alcohol saturated with hydrogen chloride 12.5 g (0.1 M) of monocyanoethylated methylethylketone [2] were added drop by drop while the flask was cooled with ice. The mixture was allowed to stand overnight. Then 0.5 ml of concentrated sulfuric acid was added and the mixture was boiled for 30 min, after which the alcohol was evaporated and the remainder poured into a 2 N aqueous solution of soda. After the usual treatment 13.7 g (80%) of the substance were obtained.

B.p. 102-105° (10 mm), $n^{20}D$ 1.4310, d^{20}_4 0.9795. Literature data: b.p. 95° (5 mm), $n^{20}D$ 1.4300, d^{20}_4 0.9803[2].

The ethyleneketal of the ethyl ester of γ-acetylvaleric acid. A mixture of 8.6 g (0.05 M) of the ester, 0.2 g of p-toluenesulfonic acid, 6.2 g (0.1 M) of ethylene glycol and 60 ml of benzene was boiled for three hours in a flask attached to a water separator. On completion of the heating the mixture was poured into a 2 N solution of soda. The benzene layer was separated and dried over magnesium sulfate. After redistillation, 6.4 g (56%) of the product was obtained.

B.p. 120-123° (10 mm), $n^{20}D$ 1.4438, d^{20}_4 1.0350, MR_D 55.39, $C_{11}H_{20}O_4$. Calculated 55.74.

Found %: C 61.23, 61.03; H 9.46, 9.28. $C_{11}H_{20}O_4$. Calculated %: C 61.06; H 9.32.

The ethyleneketal of γ-acetoamyl alcohol. 13.0 g (0.06 M) of freshly distilled ethyleneketal of the ester of γ-acetylvaleric acid were added to a mixture of lithium aluminium hydride (0.1 M) in 100 ml of absolute ether over the course of half an hour, with cooling. The reaction mixture was then boiled gently for 2-3 hr. Next 8 ml of water were added with vigorous mechanical stirring and cooling with ice. The solution was then decanted from the residue, and the latter extracted ten times by boiling with ether for half hour intervals and with vigorous stirring. The combined ether extracts were washed with 50 ml of a saturated solution of sodium chloride, dried over calcined potash, and the ether driven off. After redistillation, 8.1 g (80%) of the substance were obtained.

B.p. 120-121° (8 mm), $n^{20}D$ 1.4577, d^{20}_4 1.0355, MR_D 45.87. $C_9H_{18}O_3$. Calculated 46.37.

Found %: C 62.22, 61.91; H 10.19, 10.37. $C_9H_{18}O_3$. Calculated %: C 62.04; H 10.41.

γ-Acetoamyl alcohol. 7.0 g of the ethyleneketal of γ-acetoamyl alcohol were allowed to stand for 20 hr with 10 ml of 2 N hydrochloric acid. After pouring the reaction mixture on solid potash and filtering, the neutral aqueous solution of the keto alcohol was extracted ten times with ether. γ-Acetoamyl alcohol (3.0 g, 58%) had the following constants: b.p. 104-106° at 10 mm, $n^{20}D$ 1.4473, d^{20}_4 0.9784. On redistilling it in the presence of iodine, 2,3-dimethyl-Δ^2-dihydropyran (II, R = CH_3), which had properties identical with those of the product described above, was obtained. B.p. 132-135° at 755 mm, $n^{20}D$ 1.4555, d^{20}_4 0.9088.

SUMMARY

1. The reduction of δ-enollactones by means of lithium aluminium hydride leads to the formation of δ-keto alcohols which readily split off water and are converted into Δ^2-dihydropyrans (yield 30-45% based on the original δ-enollactone). This reaction is a new method for synthesizing 2,3-dialkylsubstituted Δ^2-dihydropyrans.

2. The independent synthesis of γ-acetoamyl alcohol by the reduction of the ethyleneketal of the ester of γ-acetylvaleric acid, with the subsequent removal of the ketal protection, was accomplished.

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ABSORPTION SPECTRA IN THE ULTRAVIOLET AND VISIBLE REGIONS OF DERIVATIVES OF CHROMONECARBOXYLIC-2 ACID

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Previously [1] we observed the interesting dependence of the color of the crystalline anilides of chromonecarboxylic-2 acid (I a-g) on the character of the substituent (the residue of an aromatic amine) in the para-position of the benzene ring.

R = a — H, b — CH$_3$, c — OCH$_3$, d — OH,
e — N(C$_2$H$_5$)$_2$, f — SO$_3$H, g — NO$_2$.

(Ia — g)
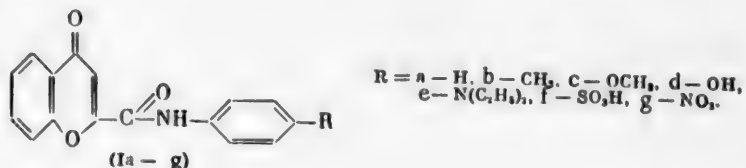
With an increase in the electron donor properties of the substituents, the color of the corresponding compounds (I a-e) becomes deeper; the introduction of electron acceptor substituents (I f, Ig) to a certain degree also deepens the color of the substance in the solid state.

In the present paper the influence of different substituents on the absorption spectra of solutions of anilides (I a-g) in the ultraviolet and visible regions is examined. Comparison of the spectra of relatively simple structures: chromone [2], 2-methylchromone [3], chromonecarboxylic-2 acid and its esters [4], and also the amide (II) and anilide (Ia) and 3-methylchromonecarboxylic-2 acid (III) (Fig. 1) with the spectra of colored anilides makes it possible to connect the appearance of some of the observed bands with the presence of the chromone system.

The absorption spectra of the simplest derivatives of chromone have two fundamental maxima: as a rule the first is more intense (log ε 3.9-4.3) ,in the interval 230-245 mμ ,and the second, which is less intense (log ε 3.8-3.9), in the 298-310 mμ. The shorter wave band is associated with the presence of the so-called "cross-coupling" (K-band), and the second with the presence of the benzene ring (B-band) in the chromone molecule [3, 5]. It is easy to observe the peculiarity of the spectrum (Ia): Under the influence of the phenyl radical the intensity and width of the long wave band (log ε 4.14) is considerably increased [almost twice, for example, in comparison with the amide (II)]. In spectrum (III) a supplementary maximum appears at 280 mμ (log ε 3.67). The appearance of a supplementary maximum (λ 268 mμ, log ε 3.816) has also been mentioned in the case of a 2,3-disubstituted chromone, namely 2,3-dimethylchromone [3]. Figures 2 and 3 show the absorption spectra of solutions of substituted anilides of chromonecarboxylic-2 acid (I b-e). The plots of the curve of the spectra of the compounds up to 340 mμ are, to a considerable degree, similar to each other. They are characterized by absorption in the 236-238 mμ (log ε 4.30-4.36) and 304-315 mμ (log ε 4.10-4.15) region, which is caused apparently by the presence of the chromone system. The intensity of these bands changes only significantly in comparison with (Ia) (Fig. 1). In spectrum (Ie) there is one more peak at 262 mμ (log ε 4.28), and a significant deviation of the (Ie) spectrum from those of other anilides also appears in the visible region. Thus, if the spectra (Ib, c, d) have only a bend at ~ 340 mμ (log ε 3.6-3.8) then in the case of (Ie) there already exists a maximum at 400 mμ (log 3.93). It should be noted that the bend mentioned above at 340 mμ is more clearly shown in the case of compound (Id) (Fig. 3). With increasing ability of the substituent in the benzene ring to donate electrons, a broadening of the long wave absorption boundaries in the visible region of the spectrum occurs. Characteristic of this is the fact that the color of these substances does not disappear even at concentrations of $2 \cdot 10^{-5}$ in alcohol solutions.
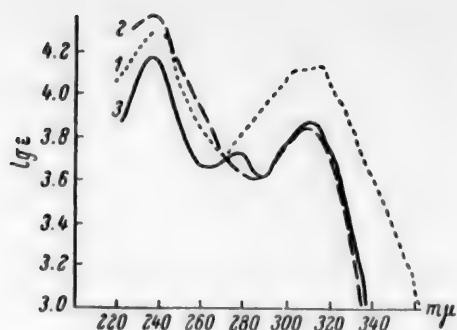
Fig. 1. Absorption spectra. 1) Anilide of chromonecarboxylic-2 acid, 2) amide of chromonecarboxylic-2 acid, 3) methylchromonecarboxylic-2- acid.

Some analogy in the absorption spectra of compounds (Ic, d, e) (especially in the long wave region) with the absorption spectra of para-methoxy-, hydroxy-, and dimethylamino-nitrobenzanilides requires attention. These absorb respectively at 326, 327, 333-336, and 380 mμ [6, 7]. The reasons for the coloring of nitrobenzanilides have been studied in considerable detail [6-8]. In the case of anilides (Ia-g) it is not impossible that one of the reasons for the color is the formation of conjugated bonds at the expense of the tautomeric CONH group.
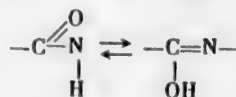
For the purpose of comparison with anilide (Id) we synthesized anilide (1h), in which there is no possibility of tautomerism.

(Ih)
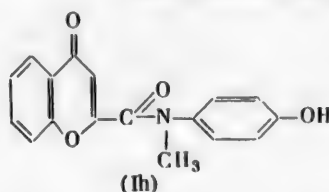
In the (Ih) spectrum absorption is considerably decreased, especially in the long wave region (340-380 mμ). It is noteworthy that even in the crystalline state compound (Ih) is almost colorless.* These facts seems to confirm the assumption previously expressed; however a final resolution of the problem will require supplementary experimental data.
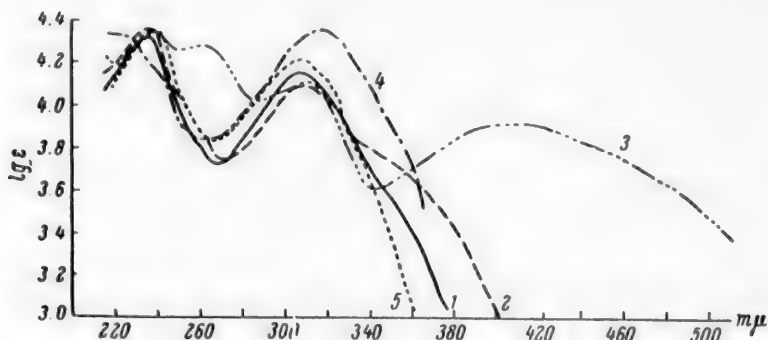
Fig. 2. Absorption spectra of para-substituted anilides of chromonecarboxylic acid: 1) methyl, 2) methoxy, 3) dimethylamino, 4) nitro, 5) sulfo.

EXPERIMENTAL

The absorption spectra were measured on a quartz SF-4 spectrophotometer. Rectified alcohol which had previously been distilled through a rectification column was used as the solvent. The concentration of the solutions varied from $2 \cdot 10^{-5}$ to $1 \cdot 10^{-4}$.

The N-methyl-p-hydroxyanilide of chromonecarboxylic-2 acid (Ih). A solution of 1.2 g of the chloroanhydride of chromonecarboxylic-2 acid in 10 ml of dichloroethane was gradually added, with ice cooling, to 2.97 g of metol sulfate and 2.9 g of sodium bicarbonate in 10 ml of water. The reaction mixture was stirred for another 30 min. Then the residue was filtered off, and washed with water, 2 N hydrochloric acid and sodium bicarbonate. 1.2 g (75%) of the anilide (Ih) were obtained. M.p. 168-168.5° (from aqueous alcohol).

*Solution of compound (1 h) in alkalies does not result in a noticeable deepening of the color (owing to the formation of phenolate). On the other hand, the phenolate of compound (1 d) has an intense orange-red color in aqueous solution.
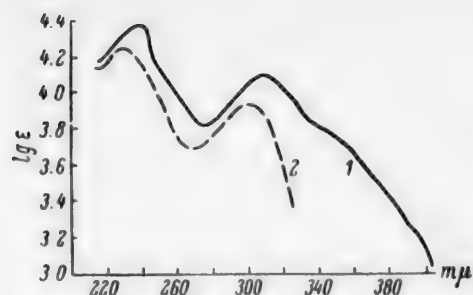
Fig. 3. Absorption spectra of anilides of chromonecarboxylic-2 acid. 1) n-hydroxy, 2) N-methyl-n-hydroxy.

Found %: C 69.46, 69.51; H 4.39, 4.39; N 5.00, 4.84. $C_{17}H_{13}O_4N$. Calculated %: C 69.12; H 4.49; N 4.73.

The structure of compound (Ih) as an N-acetyl derivative of metol was confirmed by the absence of any ability to form a chlorohydrate, and also by the data of the infrared spectrum; the latter (in the crystalline condition) has $\nu_{C = O}$ 1650 and 1636 cm^{-1}. Compound (Ic) has $\nu_{C = O}$ 1650 and 1637 cm^{-1} (cusp); compound (Id) has $\nu_{C = O}$ 1643 and 1624 cm^{-1}. In the case of the phenyl and p-methoxyphenyl esters there is a characteristic carbonyl frequency of an ester group (1755 cm^{-1}) along with an absorption band caused by the presence of the C = O group of chromone (1650 and 1670 cm^{-1}, respectively).

SUMMARY

1. The absorption spectra of solutions of para-substituted anilides of chromonecarboxylic-2 acid were studied.

2. With increasing ability of substituents in the para-position of the phenyl radical to donate electrons, a broadening of the long-wave absorption boundaries in the visible region of the spectrum occurs.

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ULTRAVIOLET SPECTRA OF HYDROXY
AND DIHYDROXYBENZILS

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It is known [1] that in the benzil molecule the planes of the benzoyl groups forming this compound are located at an angle of 90-100°.
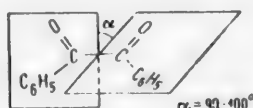
Symmetrical dimethoxy and dihydroxybenzils evidently also exist in an angular form of this kind, which is indicated by the close similarity between the absorption spectra of their alcoholic solutions and the spectra of the correspondingly substituted benzaldehydes [2].

While investigating the regrouping of hydroxy and dihydroxybenzils [3], our interest was attracted by the problem of the preferential configuration of these compounds in aqueous alkali, because regrouping took place under these conditions.

In alkali, hydroxybenzils are present in the form of the ions

and must differ essentially from unionized hydroxy and methoxybenzils by the distribution of the electron density, the conditions of intramolecular reaction, and the intramolecular ratios with the solvent. For this reason we considered that in this case too it was necessary to compare the spectra of hydroxybenzils and hydroxybenzaldehydes and obtain experimental data on the stereochemical structure of the molecules.

In the present work the ultraviolet spectra of 2-, 3-, 4-hydroxy, 2,2'-, 3,3'- and 4,4'-dihydroxybenzils were measured in 0.1 N aqueous alkali and, to obtain further details of the characteristics of these compounds, in 95% alcohol. For the comparison we employed literature data [4] on the spectra of hydroxybenzaldehydes and our own measurements of the spectra of unsubstituted benzil in alcohol and water. The results of the measurements are given in the Table and in Figs. 1-4.

It is readily noted (see Figs. 1 and 2*) that the character of the absorption curves of ionized 2,2'-, 3,3'- and 4,4'-dihydroxybenzils and the corresponding hydroxybenzaldehydes is similar. As in the case of the spectra of the dihydroxy- and dimethoxy derivatives in alcohol [2], the absorption curves of the ortho-substituted compounds are the most similar. But on the whole, a certain bathochromic displacement of the spectra of the corresponding aldehydes is characteristic of the spectra of benzils; this displacement is, however, comparatively slight. Thus, the difference in the position of the absorption maxima of benzils and aldehydes varies between 3 and 17 mμ, and only reaches 30 mμ in one case (λ° 4,4'-dihydroxybenzil and 4-hydroxybenzaldehyde), whereas in the case of glyoxal in the trans-planar form [5], the absorption maximum is displaced by 150 mμ in comparison with the maximum of formaldehyde [6].

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*For ease of comparison, in Figs. 1 and 2 the absorption coefficients of dihydroxybenzils is reduced by half (log ε is correspondingly reduced by 0.3).

Position ($\lambda\ m\mu$) and Intensity ($\log\ \varepsilon$) of the Absorption Maxima of Hydroxy and Dihydroxybenzils

Compound	Alcohol				Aqueous alkali [***]					
	λ'	$\log\varepsilon$	λ''	$\log\varepsilon$[*]	λ'	$\log\varepsilon'$	λ''	$\log\varepsilon'$	λ'''	$\log\varepsilon$[*]
2,2'-Dihydroxybenzil	257	4.19	332	3.83	~262	4.14	385	4.02		
3,3'-Dihydroxybenzil	264	4.24	325	3.75	243	4.50	281	4.15	375	3.62
4,4'-Dihydroxybenzil	223	4.19	299	4.38	244	4.02	360	4.62		
2-Hydroxybenzil	255	4.13	336	3.59	~242	4.25	402	3.65		
3-Hydroxybenzil	260	4.29	326	3.46	244	4.38	~277	4.14	~375	3.34
4-Hydroxybenzil	256	4.16	297	4.22	252	4.18	351	4.37		
Benzil	260	4.28	375—380	1.87	264	4.21	~375	1.89		

[*] An SF-4 spectrophotometer was used for the measurements.

[**] The sign ~ signifies a kink in the absorption curve.

[***] The spectrum of the aqueous solution is given for unsubstituted benzil.
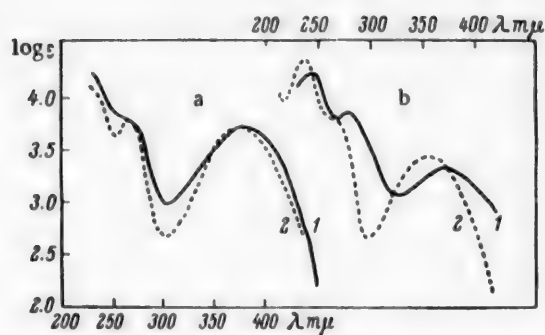
Fig. 1. Absorption spectra of dihydroxybenzils and hydroxybenzaldehydes in 0.1 N KOH a: 1) 2,2-Dihydroxybenzil; 2) 2-hydroxybenzaldehyde; b: 1) 3,3'-dihydroxybenzil; 3) 3-hydroxybenzaldehyde.
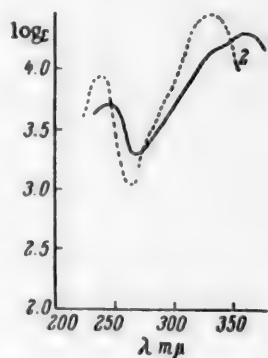
Fig. 2. Absorption spectra:
1) 4,4'-dihydroxybenzyl;
2) 4-hydroxybenzaldehyde
in 0.1 N KOH.
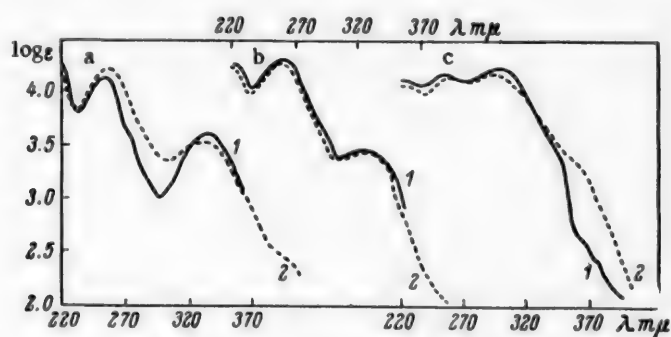
Fig. 3. Absorption spectra of hydroxybenzils in alcohol: a) 2-hydroxy, b) 3-hydroxy, c) 4-hydroxy; 1) Experimental curves; 2) half-sum of the absorption of the corresponding dihydroxy- and unsubstituted benzils in alcohol.
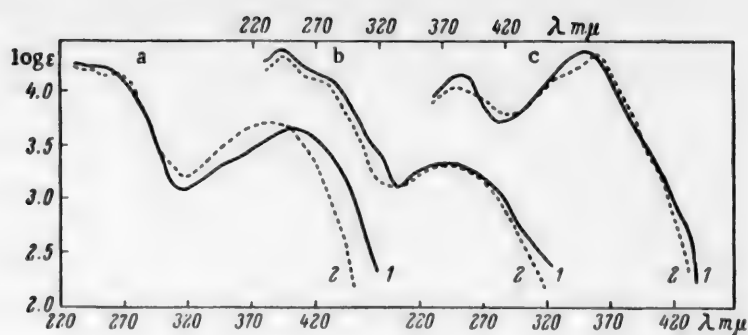
Fig. 4. Absorption spectra of hydroxybenzils in 0.1 N KOH: a) 2-hydroxy,
b) 3-hydroxy, c) 4-hydroxy; 1) Experimental curves; 2) half-sum of
the absorption of the corresponding dihydroxybenzil in 0.1 N KOH and un-
substituted benzil in water.

The reason for the incomplete agreement of the absorption curves of benzils and benzaldehydes is evidently the mutual influence of the two benzoyl groups of the diketone, which is exerted via an induction mechanism or spatially (field effect).

From an examination of Figs. 3 and 4 it is seen that both in neutral and alkaline media the character of the spectra of 2-, 3- and 4-hydroxybenzils may be depicted satisfactorily by curves representing the half-sum of the absorption of unsubstituted benzil and the corresponding dihydroxybenzils. Therefore it may be assumed that in the ionized and unionized forms, hydroxy- and dihydroxybenzils have an angular configuration.

SUMMARY

The ultraviolet spectra of hydroxy and symmetrical dihydroxybenzils in alkaline and neutral media were measured. Like unsubstituted benzil and the corresponding unionized derivatives, in the ionized form these compounds probably have an angular configuration.

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SYNTHESIS AND INVESTIGATION

OF 5-(2-METHYLTHIOETHYL) - 5 - (1-METHYLBUTYL)-

2-THIOBARBITURIC ACID

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According to literature data [1], the sodium salt of 5-(2-methylthioethyl)-5-(1-methylbutyl)-2-thiobarbituric acid (thiogenal, diogenal, nerazal) is a center of interest in modern anesthesiology and surgery because of its ultrashort effect and the absence of any secondary influences when it is employed for anesthesia; in this respect it has advantages compared with hexenal and thiopental sodium [2], which have a similar chemical structure. Thigenal not only does not depress respiration, but protects the parenchyma of the liver and does not have an unfavorable effect on the kidneys. As a result of the presence of the methylthioethyl radical (methionine) in its molecule it accelerates the transmethylation reaction in the organism, which is of exceptional importance for improving the functional state of the liver. It must be remembered that whereas fairly extensive pharmacological, biological and clinical information on thiogenal is available, there are hardly any data on its synthesis. Recent communications [3] in this field give very scant information, and patent literature give the synthesis of thiogenal in very general outlines only [4].

We synthesized thiogenal by reacting methylthioethyl-sec-amylmalonic ester with thiourea in the presence of sodium ethylate, and the intermediate products (S-methylisothiourea, β-hydroxyethylmethyl sulfide, β-chloroethylmethyl sulfide) were synthesized according to literature data [5].

$$CH_3SCH_2CH_2 \diagdown \quad COOC_2H_5 \qquad \diagup NH_2 \xrightarrow{C_2H_5ONa}$$
$$CH_3CH_2CH_2CH \diagup C \diagdown COOC_2H_5 \quad + SC \diagdown NH_2$$
$$\quad\quad | \quad CH_3$$

$$\longrightarrow \quad CH_3SCH_2CH_2 \diagdown \quad CO{-}N$$
$$\quad\quad\quad C \diagdown \quad\quad CSNa + 2C_2H_5OH$$
$$CH_3CH_2CH_2CH \diagup \quad CO{-}NH$$
$$\quad\quad | \quad CH_3$$
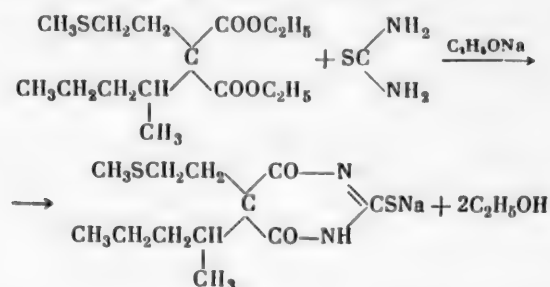
Mono-and disubstituted malonic ester, 5-methylthioethyl- and 5-methyl-thioethyl-sec-amyl derivatives of 2-thiobarbituric acid, and also the sodium salt of the latter were prepared by analogy with the syntheses of thio ethers of barbituric acid, described by Walter and his co-workers [6].

EXPERIMENTAL

Diethyl ester of β-methylthioethylmalonic acid. We added 0.3 g-mole of malonic ester to a solution of 0.3 g-at. of sodium metal in 150 ml of anhydrous alcohol. The alcohol was distilled under vacuum at 30 mm, with heating on a water bath, and 300 ml of anhydrous toluene and 0.3 g-mole of β-chloroethylmethyl sulfide were added to the residue. After 12 hr heating at 100-110° and vigorous mixing in a flask with a reflux condenser equipped with a calcium chloride tube, 200 ml of water was added with cooling, the toluene layer was separated, and after it had been dried over calcined sodium sulfate the toluene was distilled under a vacuum of 30 mm with heating on a water bath. The residue was distilled at 13 mm; 50-60% of the substance was obtained.

B.p. 153-154° (13 mm), $n^{20}D$ 1.4603.

Found %: S 13.77, 13.25. $C_{10}H_{18}O_4S$. Calculated %: S 13.67.

Diethyl ester of β-methylthioethyl-sec-amylmalonic acid. We added 0.3 g-mole of the diethyl ester of β-methylthioethylmalonic acid to a solution of 0.3 g-at. of sodium in 150 ml of anhydrous alcohol; when the material had dissolved, the alcohol was distilled at 30 mm and 300 ml of anhydrous toluene and 0.3 g-mole of 2-bromopentane (b.p. 116-118°, $n^{20}D$ 1.4418) were added to the residue. The reaction mixture was heated on an oil bath at 110-120° for 12 hr with vigorous stirring in a flask fitted with a reflux condenser with a calcium chloride tube. When the mixture had cooled, 200 ml of water was added, the toluene layer was separated and dried over sodium sulfate, and the toluene was distilled under a vacuum of 30 mm with heating on a water bath; the residue was distilled at 7 mm. The unreacted methylthioethylmalonic ester came over first, followed at 155-160° by the disubstituted ester; the yield was 50%, $n^{20}D$ 1.4678.

Found %: S 10.73, 10.86; C 59.88; H 9.29. $C_{15}H_{28}O_4S$. Calculated %: S 10.52; C 59.21; H 9.20.

5-(2-Methylthioethyl)-5-(1-methylbutyl)-2-thiobarbituric acid. A quantity of 0.2 g-mole of the disubstituted ester (b.p. 155-160° at 7 mm) and 0.24 g-mole of dry finely ground thiourea were heated for 18 hr with a solution of 0.42 g-at. of sodium metal and 150 ml of anhydrous alcohol. The latter was distilled with heating on a water bath at 30 mm, the residue was dissolved in 200 ml of water and the solution was extracted with ether. After the aqueous solution had been acidified with dilute acetic acid an emulsion was formed from which white flakes were gradually precipitated; more frequently, however, a heavy, slightly-colored oil was obtained. This was separated, washed with water and dried to constant weight in a vacuum desiccator over sulfuric acid (yield 30-35%). If kept for a long time, the oily liquid turned into a paste and then into a crystalline substance; after recrystallization from methyl alcohol, the m.p. was 79-81° [3].

Found %: N 9.98, 10.06; S 22.00, 22.32. $C_{12}H_{20}O_2N_2S_2$. Calculated %: N 9.70; S 22.22.

Sodium salt of 5-(2-methylthioethyl)-5-(1-methylbutyl)-2-thiobarbituric acid. This was made by neutralization of 5-(2-methylthioethyl)-5-(1-methylbutyl)-2-thiobarbituric acid, dissolved in the minimum amount of alcohol, with a solution of an equivalent amount of sodium metal in anhydrous alcohol. A crystalline substance was precipitated after cooling with a mixture of ice and salt; after this had been washed with alcohol it was kept in a desiccator above sulfuric acid. The yield was 82.3%. It was a light-yellow, extremely hygroscopic powder, readily soluble in water, and in alcohol, pH 10.57; it was unchanged by sterilization (100°).

Biological tests on mice, guinea pigs, rabbits and cats showed that thiogenal is less toxic than thiopental sodium. Bearing in mind that this substance does not have a toxic effect on the liver, it was tested in a clinic on a large number of chronic invalids, excellent results being obtained.

In conclusion we wish to express our thanks to S. V. Anichkov, P. E. Motovilov, and M. O. Sterin for carrying out biological and clinical tests of this compound.

SUMMARY

The condensation reaction of the diethyl ester of β-methylthioethyl-sec-amylmalonic acid with thiourea was investigated and the sodium salt of 5-(2-methylthioethyl)-5-(1-methylbutyl)-2-thiobarbituric acid was obtained.

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INVESTIGATION OF THE EFFECT OF AlCl₃,
IN A CURRENT OF HYDROGEN CHLORIDE
ON CERTAIN BROMO DERIVATIVES OF NAPHTHALENE

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A large number of reports have been devoted to investigations of the mobility of bromine or chlorine atoms in the molecule of monobromo or monochloronaphthalenes [1]. Dibromonaphthalenes have been investigated far less [2]. Our previous report [3] described an investigation of the bromine atom in a polybromonaphthalene molecule.

In the present work our aim was to determine the mobility of the bromine atom in molecules of mono-, di- and tribromonaphthalenes when they react with gaseous hydrogen chloride in the presence of aluminum chloride, and also to compare the activity of aluminum chloride, sublimated into a reaction vessel, with the activity of aluminum chloride prepared by the Radsiwanowski method [4]

In the first series of experiments we compared the activity of anhydrous aluminum chloride with the compound obtained by the Radsiwanowski method, when it acts on 1-bromonaphthalene; in the second and third series of experiments we used 1-4-dibromo and 1,4,6-tribromonaphthalene, respectively. For the investigation we used a series of naphthalene bromides in which the number of bromine atoms successively increased, the structure of any one bromide differing from the next by one bromine atom.

The results of the experiments showed that use of either catalyst leads to the same reaction products, but that far less of the Radsiwanowski aluminum chloride need be used, the reaction taking place far more rapidly when this catalyst is used. The most intense activity of the bromine atom was observed in the case of monobromonaphthalene; not only migration of the bromine atom from the α- to the β-position, but also the formation of naphthalene by detachment of bromine from the α-monobromonaphthalene molecule and further bromination of monobromonaphthalene to the dibromide took place.

Di- and tribromonaphthalenes behave differently. In the case of these bromides only intramolecular migration of the bromine atoms or their detachment, with the formation of monobromonaphthalene or naphthalene, was observed. Further bromination of either dibromo or tribromonaphthalenes was not noted. It is of interest to mention that in the previous investigation we showed [3] that under these experimental conditions 1,4,6,7-tetrabromonaphthalene does not undergo further bromination and migration of the bromine atoms does not take place, but condensation of the naphthalene rings occurs.

EXPERIMENTAL

1. The effect of aluminum chloride in a current of hydrogen chloride, and aluminum chloride obtained by Radsiwanowski's method, on α-bromonaphthalene. A quantity of 5 g of aluminum chloride was distilled into a round-bottomed flask from a retort, carbon bisulfide was added, a current of hydrogen chloride was passed and a concentrated solution of α-bromonaphthalene in carbon bisulfide (b.p. 279-290° at 767 mm) was added dropwise.

Radsiwanowski aluminum chloride was made from aluminum turnings, cut from an aluminum plate which had been thoroughly cleaned with emery paper and washed with hydrochloric acid. For the experiment we took 5 g of aluminum turnings; this was wetted with a small amount of carbon bisulfide and a current of dry hydrogen chloride was passed for 7-10 hr. The aluminum became covered with a crust of aluminum chloride. A solution of naphthalene bromide in carbon bisulfide was then added dropwise. A current of hydrogen chloride was passed for

6-8 hr. On completion of the experiment the carbon bisulfide solution was decanted from the tarry catalyst, washed with water and dried with calcium chloride. After the carbon bisulfide had been distilled, a yellow-green oil remained, from which the following fractions were separated by distillation: 1st fraction, b.p. 218-222°; this crystallized at 80°. A mixed sample with naphthalene showed no depression of the melting point.

The 2nd fraction, a yellow-green oil, distilled at 280-286°; white crystals were deposited from it on standing. After several recrystallizations from alcohol the crystals melted at 54-55°, the m.p. of the picrate was 84°. Found: M 213. Calculated: M 207. This fraction was β-bromonaphthalene in which the α-isomer was partly dissolved. To separate the isomers, the oily product was cooled, the crystallizing mixture was transferred to a porcelain filter and filtered at the pump; the liquid α-isomer rapidly passed through the filter, leaving the β-isomer on the latter.

After the 1st and 2nd fractions had been distilled, 2,6- dibromonaphthalene was isolated from the tarry residue; after several recrystallizations from alcohol it melted at 150°.

Found %: Br 57.3 $C_{10}H_6Br_2$. Calculated %: Br 55.9.

The same substances were obtained in the experiments with sublimated aluminum chloride and Radsiwanowski aluminum chloride.

2. The effect of $AlCl_3$ in a current of HCl gas on 1,4-dibromonaphthalene (m.p. 81°). The same substances were obtained in experiments with sublimated aluminum chloride and the Radsiwanowski type. The experimental conditions were the same as those described in section 1. The reaction products were β-bromonaphthalene (m.p. 55°) and 2,6-dibromonaphthalene (m.p. 156°).

3. The effect of $AlCl_3$ in a current of hydrogen chloride on 1,4,6-tribromonaphthalene (m.p. 86°). The experimental conditions were the same as before. The reaction products were two tribromonaphthalenes with m.p. of 65-67° and 138°.

Analysis of the product with m.p. 65-67°.

Found %: Br 61.44, M 362. $C_{10}H_5Br_3$. Calculated %: Br 65.75. M 365.

Analysis of the product with m.p. 138°.

Found %: Br 64.95. M 386.5. $C_{10}H_5Br_3$. Calculated %: Br 65.75. M 365.

The structure of the re-obtained tribromides was not proven.

SUMMARY

1. The effect of $AlCl_3$ obtained by the Radsiwanowski method, and $AlCl_3$ obtained by sublimation, on various bromo derivatives of naphthalene was investigated.

2. It was shown that both catalysts have the same effect on the chemical process. The reaction velocity is higher when aluminum chloride prepared by the Radsiwanowski method is used.

3. The activity of bromine atoms in mono, di- and tribromonaphthalenes was determined. In the case of α-monobromonaphthalene, not only migration of bromine atoms from the α-to the β-position is observed, but also detachment of bromine from one molecule of monobromonaphthalene and further bromination, with the formation of 2,6-dibromonaphthalenes. In the case of di- and tribromides, only migration of bromine atoms, with the formation of new isomers or detachment of bromine atoms was observed. Further bromination of di- and tribromides was not observed.

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THE SYNTHESIS OF DERIVATIVES OF THIOUREA

I. ARYL THIOCARBAMYL PIPERAZINES

N. B. Galstukhova and M. N. Shchukina

In recent years there have been reports in the literature on the antitubercular activity of certain thiourea derivatives both in vitro and in vivo [1-5]. An investigation was made of a wide range of thiourea derivatives with various groups as substituents: aryl, alkyl, aroyl, alkoxyl, heterocyclic, etc. Of these compounds the most active were N,N'-diaryl-substituted thioureas (thiocarbanilides), some of which have been employed in medical practice for the treatment of tuberculosis : ethoxide [6] (4,4'-diethoxythiocarbanilide), N-(p-dimethylamino)-N'-(p-butoxy)-thiocarbanilide [7], thioban [4] (4-(α-pyridyl)-4-(isobutoxy)-thiocarbanilide). It was also noted that β- and γ-pyridyl derivatives of thiocarbanilide have a fairly high antitubercular activity [5].

It was of interest to obtain by analogy with pyridyl derivatives of thiourea, similar compounds with different heterocyclic substituents, too, particularly with a piperazine ring. Of the piperazine derivatives, alkyl and alkoxy-phenylthiocarbamic compounds have been little investigated chemically and biologically; however, it is known that certain aryl piperazines have an antitubercular activity [8].

We obtained thiocarbamyl derivatives of piperazine of the formula

$$CH_3-N\overline{}N-\overset{\displaystyle}{\underset{\displaystyle S}{C}}-NH-\overline{}-R \quad \text{and}$$

$$R_1-\overline{}-N\overline{}N-\overset{\displaystyle}{\underset{\displaystyle S}{C}}-NH-\overline{}-R$$
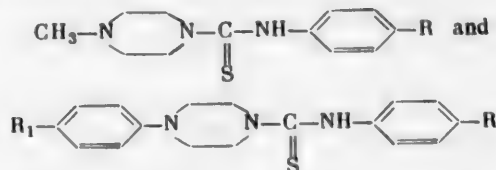
by reacting alkyl or aryl piperazine with the corresponding phenyl isothiocyanates. We obtained substituted phenyl isothiocyanates from symmetrical disubstituted thiocarbanilides : p-ethoxyphenyl isothiocyanate by boiling 4,4'-diethoxythiocarbanilide with concentrated hydrochloric acid; p-tolyl, p-methoxy and p-butoxyphenyl isothiocyanates by heating the corresponding symmetrical thiocarbanilides with concentrated phosphoric acid.

Symmetrical substituted thiocarbanilides are now comparatively readily available compounds as a result of the simple method of preparing them from the hydrochlorides of the corresponding anilides and ammonium thiocyanate [9]. The aryl-substituted piperazines necessary for the synthesis were obtained from the corresponding aryl amines and di-(β-chloroethyl)-amine [10]. Methyl piperazine was synthesized from piperazine via the carbomethoxy derivative.

The aryl thiocarbamyl-substituted alkyl and aryl piperazines synthesized by the authors are given in the table. These compounds crystallize readily and have clear melting points. In the majority of cases they are readily soluble in dichloroethane, dioxan and acetone; they are less soluble in alcohol and benzene, and insoluble in ether and water.

EXPERIMENTAL

p-Ethoxyphenyl isothiocyanate. We heated 15 g of 4,4'-diethoxythiocarbanilide in 60 ml of concentrated hydrochloric acid with boiling until an oily layer was formed (approximately 3 hr). The reaction mixture was poured into water; the insoluble residue was filtered and washed with a small quantity of water. The substance was distilled at 153-154° (15 mm). 5.5 g (65%) was obtained. The m.p. was 61.5-63° (according to [11], the m.p. is 62.5°).

Aryl Thiocarbamyl-Substituted Piperazines

$R-N(CH_2-CH_2)(CH_2-CH_2)N-C(=S)-NH-R_1$
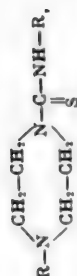
No. of compound	R	R₁	Melting point	Yield (%)	Empirical formula	Found (%)				Calculated (%)			
						C	H	N	S	C	H	N	S
(I)	C_6H_5	C_6H_5	164—166.5	95.0	$C_{17}H_{19}N_3S$	68.60	6.50	14.09	10.81	68.69	6.40	14.14	10.77
(II)	$p-CH_3C_6H_4$	C_6H_5	186—186.5	96.2	$C_{18}H_{21}N_3S$	69.35	6.79	13.43	10.20	69.45	6.75	13.50	10.29
(III)	C_6H_5	$p-CH_3C_6H_4$	182—183.5	93.6	$C_{18}H_{21}N_3S$	69.50	6.92	13.47	10.13	69.45	6.75	13.50	10.29
(IV)	$p-CH_3C_6H_4$	$p-CH_3C_6H_4$	205.5—207	72.8	$C_{19}H_{23}N_3S$	70.41	6.97	13.12	9.81	70.15	7.08	12.92	9.84
(V)	C_6H_5	$p-CH_3OC_6H_4$	195.5—196	77.5	$C_{18}H_{21}ON_3S$	66.51	6.38	13.09	9.48	66.06	6.42	12.84	9.79
(VI)	$p-CH_3C_6H_4$	$p-CH_3OC_6H_4$	196.5—197.5	96.5	$C_{19}H_{23}ON_3S$	66.61	6.90	12.22	9.31	66.86	6.74	12.32	9.38
(VII)	$p-CH_3C_6H_4$	$p-C_2H_5OC_6H_4$	201.5—203	90.2	$C_{20}H_{25}ON_3S$	67.92	7.00	11.76	9.02	67.61	7.04	11.83	9.01
(VIII)	CH_3	$p-C_2H_5OC_6H_4$	148—150	90.5	$C_{14}H_{21}ON_3S$	59.97	7.35	15.13	11.41	60.21	7.53	15.05	11.47

N-Phenyl-N'-(phenylthiocarbamyl)-piperazine (I). A solution of 4.16 g of phenyl isothiocyanate in 30 ml of anhydrous benzene was added dropwise with shaking to a boiling solution of 5 g of N-phenyl piperazine in 30 ml of anhydrous benzene. Heating of the reaction mixture was continued for 30 min. When it had cooled, the precipitate which came out was filtered and washed with benzene. 8.7 g of (I) was obtained; it gave colorless crystals from alcohol.

N-(p-Tolyl)-N'-(phenylthiocarbamyl)-piperazine (II). For the reaction, we took 1.5 g of N-tolyl piperazine, 1.15 g of phenyl isothiocyanate and 40 ml of anhydrous benzene. We obtained 2.55 g of (II); colorless crystals from benzene.

N-Phenyl-N'-(p-tolylthiocarbamyl)-piperazine (III). We took 1.67 g of N-phenyl piperazine, 1.54 g of p-tolyl isothiocyanate and 40 ml of anhydrous benzene. We obtained 3 g of (III); colorless crystals from alcohol.

N-(p-Tolyl)-N'-(p-tolylisothiocarbamyl)-piperazine (IV). We took 1g of N-tolyl piperazine, 0.85 g of p-tolyl isothiocyanate and 30 ml of anhydrous benzene. We obtained 1.36 g of (IV); colorless crystals from alcohol.

N-Phenyl-N'-(p-methoxyphenylthiocarbamyl)-piperazine (V). We took 1.96 g of N-phenyl piperazine, 2 g of p-methoxyphenyl isothiocyanate and 40 ml of anhydrous benzene. We obtained 3.07 g of (V); colorless crystals from alcohol.

N-Phenyl-N'-(p-ethoxyphenylthiocarbamyl)-piperazine (VI). We took 2 g of N-phenyl piperazine, 2.21 g of p-ethoxyphenyl isothiocyanate and 35 ml of anhydrous benzene. We obtained 4.06 g of (VI); colorless crystals from methyl alcohol.

N-(p-Tolyl)-N'-(p-ethoxyphenylthiocarbamyl)-piperazine (VII).For the reaction, we took 1.5 g of N-tolyl piperazine, 1.53 g of p-ethoxyphenyl isothiocyanate and 35 ml of anhydrous benzene. We obtained 2.73 g of (VII); colorless crystals from methyl alcohol.

N-Methyl-N'-(p-ethoxyphenylthiocarbamyl)-piperazine (VIII). We took 1 g of N-methyl piperazine, 1.79 g of p-ethoxyphenyl isothiocyanate and 26 ml of anhydrous benzene. We obtained 2.52 g of (VIII); colorless crystals from carbon tetrachloride, soluble in water with heating.

SUMMARY

Eight new compounds, substituting thiocarbamyl derivatives of piperazine, were synthesized.

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RESEARCHES IN THE IMIDAZOLE SERIES

X. AN IMPROVED METHOD OF PREPARING 2-MERCAPTOIMIDAZOLES
FROM α-HYDROXYKETONES

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A method of preparing 4,5-dialkyl(diaryl)- and 1-alkyl(aryl)-4,5-dialkyl(diaryl)-2-mercaptoimidazoles by condensing α-hydroxy ketones with ammonium thiocyanate, thiourea or its N-substituted derivatives is described in the literature [1-5].

$$R-CHOH \atop R-CO \quad + \quad {RN \atop H_2N}\!\!>\!C-SH \longrightarrow \quad {R- \atop R-}\!\!\boxed{\;}\!\!{-N \atop -N}\!\!>\!{R \atop }\!\!-SH + 2H_2O$$
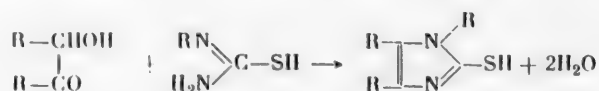
This method is of interest not only from the preparative, but also the analytical standpoint. Some aliphatic α-hydroxy ketones are difficult to isolate in the free state. The products obtained by reacting them with thiourea— —4,5-dialkyl-2-mercaptoimidazoles— are readily crystallizable, slightly soluble substances which are used to identify α-hydroxy ketones. According to the above-mentioned method [1-4] α-hydroxy ketones are reacted with thioureas in ethanol at 140-200° for 4-5 hr, using sealed tubes or autoclaves. It is of course inconvenient to work with sealed tubes at high temperatures. Therefore attempts were made [5] to carry out this reaction using a high-boiling solvent, for example, glacial acetic acid. When benzoin was condensed with thiourea 4,5-diphenyl-2-mercaptoimidazole (I) was not obtained, although under the same conditions with urea 4,5-diphenylimidazolone-2 formed quite readily. After this failure the authors abandoned the idea of using a high-boiling solvent, and they prepared (I) by fusing benzoin with thiourea at 190-200°. The latter method also has some disadvantages the most important being a considerable decomposition of the starting materials (benzoin and thiourea) at such a high temperature (190-200°), which results in a product (I) of low quality.

We reasoned that if the condensation of α-hydroxy ketones with thiourea takes place readily in ethanol at 140-200°, then it should also take place in high-boiling alcohols. When isoamyl alcohol was used in the condensation of benzoin with thiourea negative results were obtained as no reaction took place even after several hours of boiling. Apparently the boiling point of isoamyl alcohol (132°) is too low for this reaction. When benzoin was boiled with thiourea in benzyl alcohol a 36.6% yield of (I) was obtained. However benzyl alcohol did not appear to be a very suitable solvent owing to its high boiling point (204.7°).

n-Hexyl alcohol was found to be a much more suitable solvent. Its advantages include: a) a convenient boiling point (157.2°), b) immiscibility with water which makes it easy to control the course of the reaction by the quantity of water liberated, and c) low solubility of the 2-mercaptoimidazoles which are precipitated from this alcohol in a quite pure form as the reaction proceeds.

The method was studied in more detail in the case of the condensation of benzoin with thiourea. It was established that the ratio of the starting materials and duration of heating are important factors in obtaining a satisfactory yield of (I). Table 2 gives results of experiments on the dependence of the yield of (I) upon the ratio of benzoin to thiourea. All experiments were made under identical conditions: a 21.2 g (0.1 mole) sample of benzoin, 120 ml of hexyl alcohol, and a boiling time of 4.5 hr.

The data in Table 2 show that the yield of (I) based on benzoin increases sharply as the quantity of thiourea is increased, while at the same time the yield based on thiourea hardly changes.
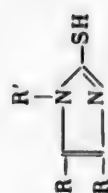
TABLE 1. 2-Mercaptoimidazoles of the General Formula
$$R-\underset{R}{\overset{R'}{\underset{|}{N}}}\underset{N}{>}-SH$$

Compound	R	R'	Yield on α-hydroxy ketone (%)	Melting point (with decomposition)	Melting point literature values	Empirical formula	Found (%)				Calculated (%)			
							C	H	N	S	C	H	N	S
(I)	C_6H_5	H	31.7	307—310°	321° (with decomp.) [1]	$C_{15}H_{12}N_2S$	71.26	4.80	11.53	12.82	71.40	4.80	11.10	12.70
(II)*	$n-C_3H_7$	H	53.8	Does not melt at 300	Does not melt at 290 [1]	$C_9H_{10}N_2S$	—	—	15.26	—	—	—	15.20	—
(III)*	$(CH_3)_2CHCH_2$	H	56.9	Does not melt at 300	Does not melt at 290 [1]	$C_{11}H_{20}N_2S$	—	—	13.64	—	—	—	13.19	—
(IV)	C_6H_5	C_6H_5	54**	Does not melt at 305	Does not melt at 290 [3]	$C_{21}H_{16}N_2S$	—	—	8.39	—	—	—	8.53	—
(V)	C_6H_5	$p-CH_3C_6H_4$	54	310—315	319—320 (with decomp.) [6]	$C_{22}H_{18}N_2S$	—	—	8.46	—	—	—	8.18	—
(VI)	C_6H_5	$p-C_2H_5OC_6H_4$	48.5	Does not melt at 305	—	$C_{23}H_{20}ON_2S$	73.91	5.52	7.70	8.23	74.16	5.41	7.52	8.61

* Compounds (II) and (III) were synthesized by V. E. Bogachev.

** When benzoin and phenylthiourea in the molar ratio of 1 : 2 were reacted under the same conditions the yield of (IV) was 66% based on benzoin.

TABLE 2

Ratio of benzoin to thiourea (in moles)	Yield of (I) (in %)	
	on benzoin	on thiourea
1 : 1	31.7	31.7
1 : 1.5	42.4	28.3
1 : 2	52.8	26.4
1 : 4	61.6	30.8

Thus, in the synthesis of derivatives of 2-mercaptoimidazole from α-hydroxy ketones and thioureas the choice of ratio of the starting materials depends upon their availability: the most favorable ratio is 1 : 1 (in moles). It was noticed that a yield of 42-56% of (I) may be obtained with a 1 : 1 molar ratio of thiourea to benzoin if the reaction mixture is boiled for 15-16 hr instead of four to five hours. A series of three experiments on the condensation of benzoin with thiourea in a 1 : 1 molar ratio using the hexanol mother liquor from a previous experiment as solvent (the boiling time in all experiments was 5.5 hr) gave the product (I) with an over-all yield of 67%.

When thiourea reacts with benzoin the formation of a by product— 4,5-diphenyl-2-aminothiazole isomeric with (I), might be expected. However we, like previous workers who studied this reaction, did not succeed in isolating 4,5-diphenyl-2-aminothiazole.

This method has been tested by condensing thiourea with aliphatic α-hydroxy ketones (butyroin, isovaleroin) and by condensing an aromatic α-hydroxy ketone (benzoin) with N-substituted thioureas (phenylthiourea, p-tolylthiourea, and p-ethoxyphenylurea). The data obtained are presented in Table 1.

EXPERIMENTAL

Synthesis of 2-mercaptoimidazoles. A mixture of 0.1 mole of an α-hydroxy ketone, 0.1 mole of thiourea, and 100-200 ml of n-hexyl alcohol was boiled in a Dean-Stark apparatus for four to five hours. After the solution had been boiling for 5-45 min crystals of 2-mercaptoimidazole began to separate, and water collected in the outlet of the apparatus (about 2.1-3.8 ml in the first two hours of boiling). When the heating was finished the reaction mixture was cooled to room temperature, the precipitate was filtered off and washed first with water (for removal of any remaining thiourea) and then with methanol, acetone, or ether (depending upon the solubility of the imidazoles obtained) and then dried. The resulting 2-mercaptoimidazole without purification was suitable for the majority of syntheses. When 2-mercaptoimidazoles were required in the pure state they were crystallized from a suitable solvent. If a particular compound was quite soluble in hexyl alcohol then an additional quantity of the 2-mercaptoimidazole was recovered by evaporating the mother liquor under vacuum.

Compounds prepared by this process were 4,5-diphenyl-2-mercaptoimidazole (I), 4,5-dipropyl-2-mercaptoimidazole (II), 4,5-diisobutyl-2-mercaptoimidazole (III),1,4,5- triphenyl-2-mercaptoimidazole (IV), 1-(p-tolyl)-4,5-diphenyl-2-mercaptoimidazole (V), and 1-(p-ethoxyphenyl)-4,5-diphenyl-2-mercaptoimidazole (VI). For analysis (I, IV-VI) were purified by crystallization from glacial acetic acid, and (II) and (III) from aqueous ethanol.

SUMMARY

An improved method of preparing 2-mercaptoimidazoles from α-hydroxy ketones and thiourea or its N-substituted derivatives has been developed in which the reaction is carried out in a high boiling solvent—n-hexyl alcohol.

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THIAZOLOBENZOTHIADIAZOLES

AND THIAZOLOBENZOSELENODIAZOLES

AND DYES PREPARED FROM THEM

S. G. Fridman

In previous papers the products of the condensation of o-diamino derivatives of 2-methylbenzothiazole with α-dicarbonyl compounds and carboxylic acids were described. These reactions produced three series of isomeric thiazoloquinoxalines [1] and thiazolobenzimidazoles [2].

The objectives of the present work were to condense o-diamino derivatives of 2-methylbenzothiazole with thionyl chloride and selenious acid, to prepare quaternary salts from the resulting thiazolobenzothiadiazoles and thiazolobenzoselenodiazoles, and to synthesize cyanine dyes from them. Dyes of this type have not been described up to the present time.

It is known that benzo-2,1,3-thiadiazole is formed by reacting o-phenylenediamine with sulfurous acid or thionyl chloride, and that benzo-2,1,3-selenodiazole is obtained with selenious acid [3]. We prepared 2-methyl-thiazolobenzo-2',1',3'-thiadiazoles by reacting thionyl chloride with o-diamino derivatives of 2-methylbenzothiazole, and by using selenious acid we obtained 2-methylthiazolobenzo-2',1',3'-selenodiazoles having the following structures.*

2-Methylthiazolo(4,5-g)benzo-2',1',3'-thiadiazole (I)

2-Methylthiazolo(4,5-g)benzo-2',1',3'-selenodiazole (II)

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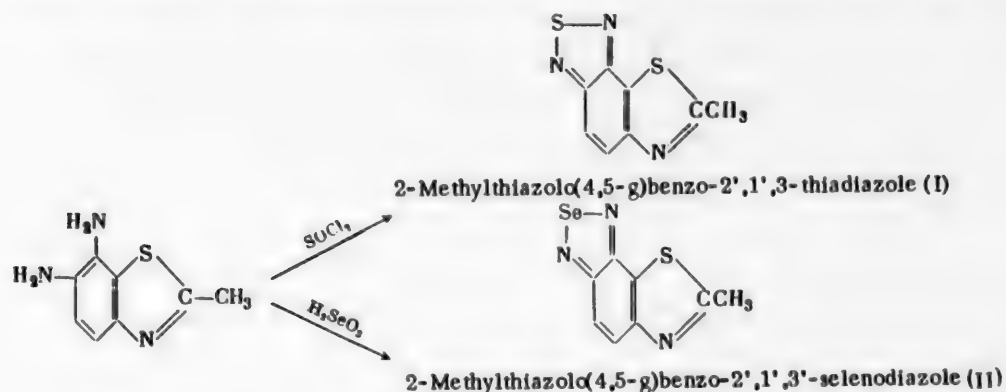
*Based on the method of preparation and some chemical properties structures containing quadrivalent sulfur and quadrivalent selenium were attributed previously to benzo-2,1,3-thiadiazole and benzo-2,1,3-selenodiazole. In the meantime measurement of interatomic distances, a study of the ultraviolet absorption spectra, and data obtained by a detailed investigation of the chemical properties of benzo-2,1,3-thia- and selenodiazoles have shown that they have a quinoid structure [4].

where Y = S, Se.

2-Methylthiazolo(5,4-g)benzo-2',1',3',thiadiazole (III)

2-Methylthiazolo(5,4-g)benzo-2',1',3'-selenodiazole
(IV)

2-Methylthiazolo(4,5-f)benzo-2',1',3'-thiadiazole (V)

2-Methylthiazolo(4,5-f)benzo-2',1',3'-selenodiazole
(VI)
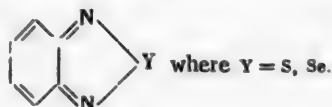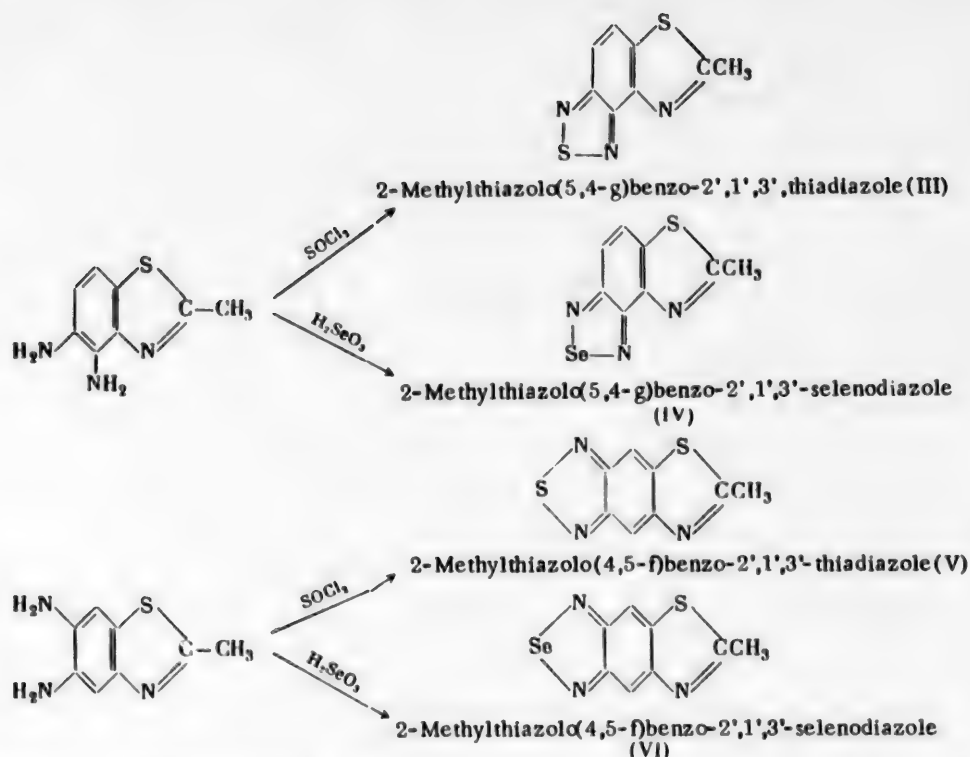
2-Methylthiazolobenzothiadiazoles are almost colorless crystalline compounds, soluble in alcohol and other organic solvents, and slightly soluble in water. 2-Methylthiazolobenzoselenodiazoles are light yellow in color and melt above 200°. They are much less soluble than 2-methylthiazolobenzothiadiazoles in alcohol and organic solvents. These products were purified by recrystallization from n-butyl alcohol.

The ultraviolet absorption spectra of 2-methylthiazolobenzothiadiazoles and 2-methylthiazolobenzoselenodiazoles in alcoholic solution were recorded. The absorption curves of thiazolobenzothiazoles (1,3,5) are shown in Fig. 1, and the absorption curves of thiazolobenzoselenodiazoles (2,4,6) in Fig. 2.
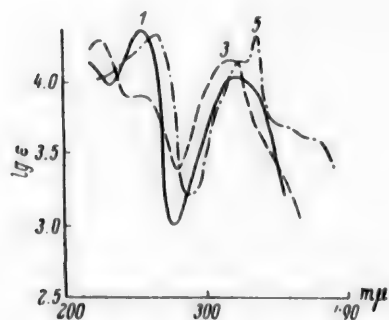
Fig. 1. Ultraviolet absorption spectra.
1) 2-Methylthiazolo-(4,5-g)benzo-2',
1',3'-thiadiazole (I); 3) 2-methylthia-
zolo(5,4-g)-benzo-2',1',3'-thiadiazole
(III); 5) 2-methylthiazolo(4,5-f)benzo-
2',1',3'-thiadiazole (V).
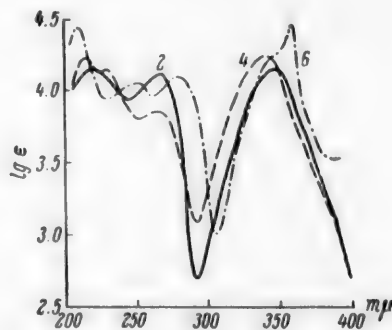
Fig. 2. Ultraviolet absorption spectra.
2) 2-Methylthiazolo(4,5-g)benzo-
2',1',3'-selenodiazole (II); 4) 2-methyl-
thiazolo(5,4-g)benzo-2',1',3'-seleno-
diazole (IV); 6) 2-methylthiazolo(4,5-f)-
benzo-2',1',3'-selenodiazole (VI).

TABLE 1
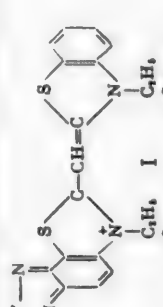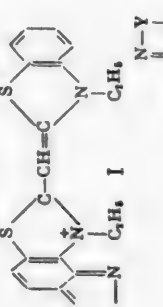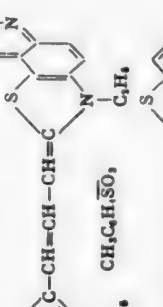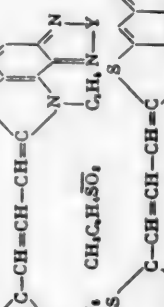
Structure	Y=S				Y=Se			
	no. of dye	yield (in %)	melting point	λ_{max} (mμ)	no. of dye	yield (in %)	melting point	λ_{max} (mμ)
(structure)	(VII)	40	281°	443	(VIII)	45	273°	415
(structure)	(IX)	65	285	442	(X)	28	283	425
(structure)	(XI)	67	268—269	600	(XII)	26	289	618
(structure)	(XIII)	87	266—267 (decomp.)	596	(XIV)	71	282	608
(structure)	(XV)	15	270 (not sharp)	593				

TABLE 1 (Cont'd)

Structure	Y = S				Y = Se			
	no. of dye	yield (in %)	melting point	λ_{max} (mμ)	no. of dye	yield (in %)	melting point	λ_{max} (mμ)
Structure 1	(XVI)	34	221—222	692	(XVII)	14	218	709
Structure 2	(XVIII)	29	222—223	687	(XIX)	41	239	697
Structure 3					(XX)	22	165	809
Structure 4					(XXI)	20	210	793
Structure 5	(XXII)	60	260	583	(XXIII)	66	215 (decomp.)	593

TABLE 1 (Cont'd)
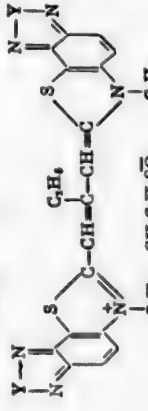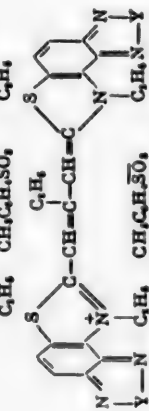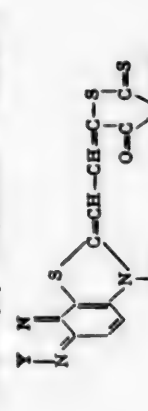
Structure	Y=S				Y=Se			
	no. of dye	yield (in %)	melting point	λ_{max} (mμ)	no. of dye	yield (in %)	melting point	λ_{max} (mμ)
	(XXIV)	81	259 (decomp.)	580	(XXV)	67	276	585
	(XXVI)	50	269—270	575	(XXVII)	36	272—273	589
	(XXVIII)	35	246	570	(XXIX)	43	241	580
	(XXX)	88	278	492	(XXXI)	53	—	500
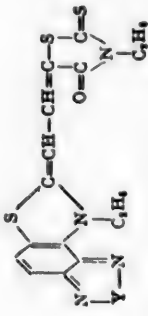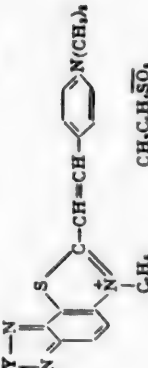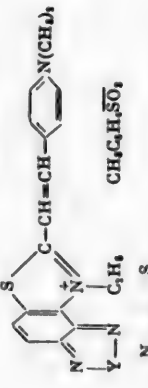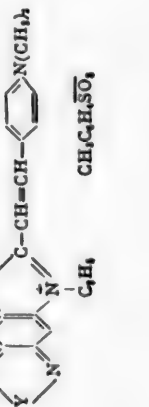
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TABLE 1 (Cont'd)

Structure	Y=S				Y=Se			
	no. of dye	yield (in %)	melting point	λ_{max} (mμ)	no. of dye	yield (in %)	melting point	λ_{max} (mμ)
	(XXXII)	73	281	498	(XXXIII)	83	308—309	512
	(XXXIV)	83	262	554	(XXXV)	41	274	552
	(XXXVI)	85	263	544	(XXXVII)	62	295	540
	(XXXVIII)	27	258	586				

TABLE 2

No. of dye	Empirical formula	Found (%)			Calculated (%)		
		N	S	I	N	S	I
(VII)	$C_{19}H_{17}N_4S_3I$	—	—	24.08, 24.31	—	—	24.23
(VIII)	$C_{19}H_{17}N_4S_2SeI$	9.76, 9.89	—	22.26, 22.23	9.80	—	22.22
(IX)	$C_{19}H_{17}N_4S_3I$	—	—	24.00, 24.18	—	—	24.23
(X)	$C_{19}H_{17}N_4S_2SeI$	—	—	22.38, 22.44	—	—	22.22
(XI)	$C_{28}H_{24}O_3N_6S_5$	—	24.12, 23.91	—	—	24.54	—
(XII)	$C_{28}H_{24}O_3N_6S_3Se_2$	10.96, 10.93	—	—	11.26	—	—
(XIII)	$C_{28}H_{24}O_3N_6S_5$	—	24.06, 24.09	—	—	24.54	—
(XIV)	$C_{28}H_{24}O_3N_6S_3Se_2$	10.82, 10.90	—	—	11.26	—	—
(XV)	$C_{28}H_{24}O_3N_6S_5 \cdot H_2O$	—	23.39, 23.25	—	23.25	—	—
(XVI)	$C_{30}H_{26}O_3N_6S_5 \cdot 2H_2O$	—	22.17, 22.29	—	22.40	—	—
(XVII)	$C_{30}H_{26}O_3N_6S_3Se_2$	10.47, 10.40	—	—	10.88	—	—
(XVIII)	$C_{30}H_{26}O_3N_6S_5 \cdot 2H_2O$	—	22.70, 22.63	—	—	22.40	—
(XIX)	$C_{30}H_{26}O_3N_6S_3Se_2$	10.73, 10.69	—	—	10.88	—	—
(XX)	$C_{32}H_{25}O_3N_6S_3Se_2$	10.26, 10.17	—	—	10.52	—	—
(XXI)	$C_{32}H_{29}O_3N_6S_3Se_2$	11.10, 11.11	—	—	10.52	—	—
(XXII)	$C_{21}H_{19}N_4S_3I$	—	—	23.33, 23.16	—	—	23.09
(XXIII)	$C_{21}H_{19}N_4S_2SeI$	—	—	20.96, 21.07	—	—	21.27
(XXIV)	$C_{21}H_{19}N_4S_3I$	—	17.35, 17.17	23.17, 23.32	—	17.45	23.09
(XXV)	$C_{21}H_{19}N_4S_2SeI$	—	—	21.26, 21.28	—	—	21.27
(XXVI)	$C_{30}H_{26}O_3N_6S_5$	—	23.38, 23.40	—	—	23.53	—
(XXVII)	$C_{30}H_{26}O_3N_6S_3Se_2$	10.56, 10.57	—	—	10.87	—	—
(XXVIII)	$C_{30}H_{28}O_3N_6S_5$	—	23.17, 23.15	—	—	23.53	—
(XXIX)	$C_{30}H_{26}O_3N_6S_3Se_2$	10.40, 10.59	—	—	10.87	—	—
(XXX)	$C_{16}H_{14}ON_4S_4$	—	30.90, 30.97	—	—	31.52	—
(XXXI)	$C_{16}H_{14}ON_4S_3Se$	11.78, 11.81	—	—	12.36	—	—
(XXXII)	$C_{16}H_{14}ON_4S_4$	—	30.82, 30.92	—	—	31.52	—
(XXXIII)	$C_{16}H_{14}ON_4S_3Se$	11.87, 11.90	—	—	12.36	—	—
(XXXIV)	$C_{26}H_{26}O_3N_4S_3$	—	17.92, 18.02	—	—	17.84	—
(XXXV)	$C_{26}H_{26}O_3N_4S_2Se$	9.44, 9.52	—	—	9.57	—	—
(XXXVI)	$C_{26}H_{26}O_3N_4S_3$	—	17.98, 17.79	—	—	17.84	—
(XXXVII)	$C_{26}H_{26}O_3N_4S_2Se$	9.38, 9.31	—	—	9.57	—	—
(XXXVIII)	$C_{26}H_{26}O_3N_4S_3 \cdot H_2O$	—	17.00, 16.93	—	—	17.25	—

Monoquaternary salts were formed by heating 2-methylthiazolobenzothia- and benzoselenodiazoles with dimethyl sulfate, diethyl sulfate or with ethyl p-toluenesulfonate. The alkyl group attached itself to the nitrogen atom of the thiazole ring, where the electronic density is greater than at the nitrogen atom of the thiadiazole or selenodiazole nucleus.

Isomers (I) and (III) of 2-methylthiazolobenzothiadiazole formed crystalline quaternary salts in good yields. Isomer (V) (linear) also gave a crystalline quaternary salt, but the yield was very small. It was much more difficult to convert 2-methylthiazolobenzoselenodiazoles into the quaternary salts. The linear isomer (VI) of thiazolobenzoselenodiazole hardly reacted at all with dimethyl sulfate and ethyl p-toluenesulfonate, and we did not succeed in isolating its quaternary salt.

The quaternary salts were converted into cyanine and styryl dyes by the usual method. Their structures, yields (before recrystallization), melting points, and absorption maxima are shown in Table 1. Analytical data are presented in Table 2. The data of Table 1 show that dyes with thiazolobenzothia- and benzoselenodiazole nuclei are deeply colored. The shift in the absorption maximum in the long-wave region of the spectrum for trimethine dyes with thiazolobenzothiadiazole nuclei as compared with 3,3'-diethylthiacarbocyanine (λ_{max} 558 mμ) amounts to 35-42 mμ, and in the case of thiazolobenzoselenodiazole nuclei the shift is 60 mμ.

The basicity of the heterocyclic rings in the structure of dyes may be estimated from values of the absorption maxima of unsymmetrical carbocyanines. In the case of unsymmetrical trimethine dyes with thiazolobenzothia- and benzoselenodiazole nuclei (dyes XXII, XXIII, XXIV, and XXV) no deviation [5] was observed. Consequently the difference in basicity between a benzothiazole (pK_a 1.23), a thiazolobenzothiadiazole, and a thiazolobenzoselenodiazole is not very great.

We were interested in determining the basicity of the symmetrical trimethine dyes which we had synthesized. For this purpose we used the method of A. I. Kiprianov and L. S. Pupko [6]. This method consists in finding the concentration of hydrochloric acid which reduces the color of the dye in alcoholic solution to half value. It was found that dyes with thiazolobenzothiadiazole nuclei exhibit very weakly basic properties. To decolorize 3,3'-diethylthiacarbocyanine by 50% required 2.66 moles of hydrogen chloride per liter of solution; the same quantity of acid decolorized dye (XI) by 12.2%, and its isomer (dye XIII) was decolorized by 42% at this concentration. A similar situation was observed in the case of the basicity of dyes with isomeric naphthothiazole nuclei. A symmetrical dye derived from 2-methyl-α-naphthothiazole (A) was less basic than a symmetrical dye from 2-methyl-β-naphthothiazole (B). The hydrogen chloride required to decolorize dye (A) by 50% was 2.27 moles per liter of solution, and for dye (B)— 1.15 moles [6].

Determination of the basicity of symmetrical trimethine dyes containing thiazolobenzoselenodiazole nuclei by decolorization of the dye with hydrochloric acid was unsuccessful because of the very low solubility of the chlorides formed by the reaction of the acid with the dye.

Dyes with the thiazolo(4,5-g)benzothia- and selenodiazole nuclei (XI, XII, XVI, XVII, XX, XXII, XXIII, XXVI, XXVII, XXXIV, XXXV) were more deeply colored than dyes with the isomeric thiazolo(5,4-g)benzothia- and selenodiazole rings (XIII, XIV, XVIII, XIX, XXI, XXIV, XXV, XXVIII, XXIX, XXXVI, XXXVII). The same phenomenon was observed in the case of the thiacarbocyanines derived from the isomeric 2-methylnaphthothiazoles. The dye from 2-methyl-α-naphthothiazole was more deeply colored (λ_{max} 597 mμ) than the dye from 2-methyl-β-naphthothiazole (λ_{max} 594 mμ). The reverse phenomenon was observed in the case of the merocyanines (XXX, XXXI, XXXII, XXXIII).

Dyes with thiazolobenzothiadiazole and thiazolobenzoselenodiazole nuclei are crystalline compounds with a metallic luster. Dyes with thiazolobenzothiadiazole nuclei were purified by recrystallization from alcohol. Dyes with thiazolobenzoselenodiazole nuclei were only slightly soluble in alcohol. These dyes were purified by dissolving them in a large quantity of alcohol, filtering the solutions and evaporating them to a small volume. Dicarbo- and tricarbocyanines were purified by simply washing them with solvents, and monomethine cyanines were recrystallized from ethylene glycol.

The absorption curves of dyes with thiazolobenzothia- and benzoselenodiazole nuclei were quite similar in shape to the absorption curves of thiacarbocyanines.

EXPERIMENTAL

2-Methylthiazolo(4,5-g)benzo-2',1',3'-thiadiazole (I) was prepared by a method similar to the improved method of A. M. Khaletskii and co-workers [7] for synthesizing benzo-2,1,3-thiadiazole. A mixture of 4.2 g of 2-methyl-6,7-diaminobenzothiazole [1], 6.5 ml of thionylaniline, and 30 ml of dry benzene was boiled on a water bath for three hours. The residue after distilling off the solvent was treated with 5% hydrochloric acid and washed with water. After crystallizing the product from alcohol 3.7 g (75%) of almost colorless needles melting at 140° was obtained. Absorption maxima were found at 255 and 320 mμ; the corresponding log ε values were 4.75 and 4.02.

Found %: S 31.01, 31.11, C 46.77, 46.51; H 2.82, 2.75. $C_8H_5N_3S_2$. Calculated %: S 30.91; C 46.38; H 2.82.

2-Methylthiazolo(5,4-g)benzo-2',1',3'-thiadiazole (III) was prepared similarly from 2-methyl-4,5-diaminobenzothiazole (4.2 g) and thionylaniline (6.5 ml). It was recrystallized from alcohol, weight 3.36 g (67%), m.p. 167°. Absorption maxima at 255 and 322 mμ; log ε 3.91, 4.16, respectively.

Found %: S 30.96, 30.93. $C_8H_5N_3S_2$. Calculated %: S 30.91.

2-Methylthiazolo(4,5-f)benzo-2',1',3'-thiadiazole (V), was prepared similarly from 4.2 g of 2-methyl-5,6-diaminobenzothiazole [1] and 6.5 ml of thionyl aniline. It was recrystallized from n-butyl alcohol. Weight of product 3.74 g (77%), m.p. 188°. Absorption maxima at 265, 325, and 337 mμ; log ε 4.32, 4.14, and 4.28, respectively.

Found %: S 30.97, 31.16. $C_8H_5N_3S_2$. Calculated %: S 30.91.

2-Methylthiazolo(4,5-g)benzo-2',1',3'-selenodiazole (II). A hot solution of 1.4 g of selenious acid in 10 ml of water was added to a stirred, hot solution of 2.6 g of 2-methyl-6,7-diaminobenzothiazole in 30 ml of alcohol. A light-yellow precipitate of thiazolobenzoselenodiazole formed immediately. After an hour it was filtered off, washed with water and methyl alcohol and recrystallized from n-butyl alcohol. Yield 3.1 g (81%), m.p. 192°. Afsorption maxima at 212, 267, and 349 mμ; log ε 4.15, 4.12, and 4.15, respectively.

Found %: N 16.44, 16.38. $C_8H_5N_3SSe$. Calculated %: N 16.53.

2-Methylthiazolo(5,4-g)benzo-2',1',3'-selenodiazole (IV) was prepared similarly from 2-methyl-4,5-diamino-benzothiazole and was recrystallized from butyl alcohol. Yield 83%. For analysis the base was recrystallized once more from methyl alcohol; m.p. 206° (light-yellow rhombic crystals). Absorption maxima at 214, 267, and 340-343 mμ; log ε 4.22, 3.88, and 4.29, respectively.

Found %: N 16.30, 16.29. $C_8H_5N_3SSe$. Calculated %: N 16.53.

2-Methylthiazolo(4,5-f)benzo-2',1',3'-selenodiazole (VI) was prepared from 2-methyl-5,6-diaminobenzothia-zole using a method similar to that used for (II) and was recrystallized from butyl alcohol. Yield 79%, m.p. 231°. Large yellow needles (from methyl alcohol). Absorption maxima at 208, 254, 278, and 358 mμ; log ε 4.43, 4.06, 4.10, and 4.43, respectively.

Found %: N 16.67, 16.79. $C_8H_5N_3SSe$. Calculated %: N 16.53.

p-Toluenesulfonate of 2-methyl-3-ethylthiazolo(4,5-g)benzo-2',1',3'-thiadiazole. A mixture of 2 g of 2-methylthiazolobenzothiadiazole (I) and 2 g of ethyl p-toluenesulfonate was heated for four hours on an oil bath at 120-130°. The fused product was triturated with 10 ml of warm acetone, and the resulting light-green residue was filtered off and washed with acetone and ether. Weight of residue 2.02 g (51%). For analysis it was converted into the iodide and recrystallized from alcohol; m.p. 250-251°.

Found %: I 35.15, 35.22. $C_{10}H_{10}N_3S_2I$. Calculated %: I 34.98.

p-Toluenesulfonate of 2-methyl-3-ethylthiazolo(5,4-g)benzo-2',1',3'-thiadiazole was prepared similarly from 2 g of the base (III) and 2 g of ethyl p-toluenesulfonate. Weight of residue after washing with acetone and ether was 3 g (76%). For analysis the p-toluenesulfonate was converted into the iodide and recrystallized from alcohol; m.p. 205-206°.

Found %: J 35.26, 35.10. $C_{10}H_{10}N_3S_2I$. Calculated %: I 34.98.

The perchlorate was prepared by precipitation from an aqueous solution of the p-toluenesulfonate with a 20% solution of sodium perchlorate. After crystallization from alcohol colorless needles were obtained.

Found %: Cl 11.38, 11.47. $C_{10}H_{10}O_4N_3S_2Cl$. Calculated %: Cl 11.69.

We were unable to prepare the quaternary salt of isomer (V) in an analytically pure form.

p-Toluenesulfonate of 2-methyl-3-ethylthiazolo(4,5-g)benzo-2',1',3'-selenodiazole. A mixture of 2 g of compound (II) and 2 g of ethyl p-toluenesulfonate was heated for four hours on an oil bath at 140-150°. The black fused product was dissolved in water, the solution was filtered to remove insoluble matter and extracted twice with small portions of ether, after which the aqueous solution was treated with charcoal and the filtrate evaporated to dryness on a water bath. The darkly colored residue was triturated with dry acetone, then with dry ether and dried in a vacuum desiccator. Weight 1.8 g (50%). For analysis the toluenesulfonate (0.5 g) was dissolved in a small quantity of water, and a saturated solution of potassium iodide was added to this solution. After standing, light-yellow needles (0.56 g, 69%) crystallized out of the solution; they had a m.p. of 223-224° after crystallization from methyl alcohol.

Found %: I 31.09, 31.16. $C_{10}H_{10}N_3SSeI$. Calculated %: I 30.97.

p-Toluenesulfonate of 2-methyl-3-ethylthiazolo(5,4-g)benzo-2',1',3'-selenodiazole was prepared similarly from (IV). Yield of crude product 1.9 g (54%). For analysis it was converted into the iodide and recrystallized from alcohol. Yield 77%; light-yellow plates with m.p. 195°.

Found %: I 30.87, 30.77. $C_{10}H_{10}N_3SSeI$. Calculated %: I 30.97.

We were unable to prepare the quaternary salt of 2-methylthiazolo(4,5-f)benzo-2',1',3'-selenodiazole (VI).

Monomethine cyanines (VII, VIII, IX, X) were prepared by boiling for one hour mixtures of the p-toluene-sulfonates of the corresponding bases with 2-methylmercaptobenzothiazole ethiodide in anhydrous alcohol in the presence of sodium bicarbonate or triethylamine. The precipitated dyes were filtered off the following day, washed with water, benzene, alcohol, and ether, and then recrystallized from ethylene glycol.

Trimethine cyanines (XI,XII,XIII,XIV,XV) were prepared by heating equal mixtures of the quaternary salts and triethyl orthoformate in pyridine. The precipitated dyes were filtered off the following day, washed with water and benzene until the filtrates became colorless, and then with alcohol and ether. Trimethine cyanines with thiazolobenzothiadiazole nuclei were recrystallized from alcohol. Trimethine cyanines with thiazolobenzoselenodiazole nuclei were purified by crystallization from a large quantity of alcohol.

Mesosubstituted trimethine cyanines (XXVI, XXVII, XXVIII, XXIX) were prepared similarly by boiling the quaternary salts with the o-propionic ester for one and one half hours.

Pentamethine cyanines (XVI, XVII, XVIII, XIX) were prepared by heating at $120°$ for 30 min the p-toluenesulfonates of the bases with the hydrochloride of dianilmalonic aldehyde in pyridine in the presence of a few drops of acetic anhydride. The dyes were purified by washing with water, benzene, alcohol, and ether.

Heptamethine cyanines (XX, XXI) were prepared by gently heating alcoholic solutions of the quaternary salts and the hydrochloride of dianilglutaconic aldehyde in the presence of piperidine for ten minutes. The precipitated blue-green dyes were filtered after 30 min, washed with benzene until the filtrates became colorless, and then with alcohol and ether. Amorphour powders with a reddish metallic luster were obtained.

Merocyanines (XXX, XXXI, XXXII, XXXIII) were prepared by heating equimolar quantities of the p-toluenesulfonates of the bases with acetanilidomethylene-N-ethylrhodanine in anhydrous alcohol in the presence of triethylamine for 15 min. The dyes were purified by recrystallization from pyridine.

Styryl dyes (XXXIV- XXXVIII) were prepared by heating the quaternary salts with p-dimethylaminobenzaldehyde in acetic anhydride for 25 minutes and recrystallizing them from alcohol.

SUMMARY

1. Three isomeric 2-methylthiazolobenzo-2',1',3'-thiadiazoles and three isomeric 2-methylthiazolobenzo-2',1',3'-selenodiazoles were prepared by reacting o-diamino derivatives of 2-methylbenzothiazole with thionyl chloride and selenious acid.

2. 2-Methylthiazolobenzo-2',1',3'-thia- and benzoselenodiazoles formed monoquaternary salts.

3. Monomethine cyanines, symmetrical, unsymmetrical, and meso-substituted trimethine cyanines, pentamethine cyanines, heptamethine cyanines, merocyanines, and styryls, containing thiazolobenzothia- and benzoselenodiazole rings were prepared.

4. It was established that addition of a thia- or selenodiazole nucleus to the benzothiazole ring caused a marked shift of the absorption maximum of the corresponding dye in the long-wave region of the spectrum.

5. The basicity of trimethine cyanines containing thiazolobenzothiadiazole nuclei was found to be very small.

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FLUOROMETHYL ESTERS OF SULFURIC ACID

II. HEXAFLUORODIMETHYLSULFATE

G. A. Sokol'skii and M. A. Dmitriev

According to present opinion [1] electrolysis of solutions of esters of carboxylic acids in hydrogen fluoride always is accompanied by destruction of the ester bond and formation of the corresponding fluorosubstituted acid as a result of fluorination of the acid fluoride. Nevertheless, by the electrochemical fluorination of the methyl ester of chlorosulfonic acid, the difluoro- and trifluoromethyl esters of fluorosulfonic acid were obtained [2]. Here we can assume that with small anode current density (0.006 a / cm^2 and below) the fluorination process is not accompanied by decomposition of the starting ester. For further confirmation of this idea, we give in the present work the results of a study of a "mild" electrochemical fluorination of one more example of an ester, dimethyl sulfate.

It was found that the optimal conditions for the electrolysis are: electrolyte, 5-10% solution of dimethyl sulfate in liquid hydrogen fluoride; potential difference 5-7 v; anode current density $0.004-0.006$ a / cm^3 temperature of electrolyte 0-5°; temperature of reflux condenser $-10°$. Under these conditions a mixture of gaseous products is formed which condenses at $-78°$ as a colorless liquid. Increasing the anode current density leads to preferential formation of fluorine oxide, which is associated with explosive gaseous reaction products.

The condensate obtained in the electrolysis was fractionated in a low temperature column. The first fraction consisted of two individual compounds, one of which was isolated in free form (hexafluorodimethyl ether) and the other dissolved in aqueous alkali (sulfuryl fluoride). The latter fraction, in addition, was a mixture of two substances; when this mixture was washed with aqueous alkali one compound (hexafluorodimethyl sulfate) was isolated in individual form, and the other was hydrolyzed with evolution of carbon monoxide, forming sulfuric and fluorosulfuric acids [2]. The isolation of the products of electrochemical fluorination of 50 g of dimethyl sulfate (0.3970 mole) and their molar quantities in the gaseous reaction mixture are given in the table.

We can assume that during electrolysis there is stepwise fluorination of dimethyl sulfate.

$$\underset{CH_3-O}{\overset{CH_3-O}{>}}SO_2 \xrightarrow[-HF]{2F\cdot} \underset{CH_3-O}{\overset{CH_2F-O}{>}}SO_2 \rightarrow \ldots \rightarrow \underset{CHF_2-O}{\overset{CF_3-O}{>}}SO_2 \xrightarrow[-HF]{2F\cdot} \underset{CF_3-O}{\overset{CF_3-O}{>}}SO_2$$

The isolation in the electrolytic bath of the comparatively high boiling hexafluorodimethyl sulfate (b.p. 29.5°) is explained by its limited solubility in hydrogen fluoride and its removal from the electrolyte in a stream of lower boiling fluorination products. The absence in the reaction product of partly fluorinated dimethyl sulfates is evidently connected with the relatively low vapor pressure of these compounds, due to which they are not removed from the reaction zone and undergo further conversion.

Along with the basic fluorination process there is decomposition of the fluorosubstituted dimethyl sulfates which are formed, accompanied by splitting of one or even two alkoxy groups. As a result of the destruction there are formed fluorosubstituted methyl esters of fluorosulfonic acid, fluorinated methyl ethers, sulfuryl fluoride, and fluorine oxide, for example:

$$CF_3-O-SO_2-O-CF_3 + F\cdot \rightarrow CF_3-O-SO_2-F + CF_3-O\cdot$$
$$CF_3-O-SO_2-O-CF_3 + 4F\cdot \rightarrow 2CF_3\cdot + SO_2F_2 + OF_2$$
$$CF_3-O\cdot + CF_3\cdot \rightarrow CF_3-O-CF_3.$$
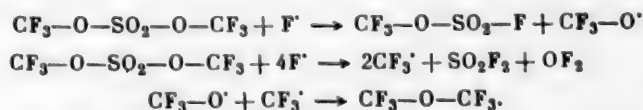
The formation of fluorinated methanes is also not excluded, as is shown by some differences in conversion on carbon and sulfur (see table), and also by differences in the amount of hydrogen evolved as calculated from the current and as actually collected (respectively 159.5 and 168 liters).

Fluorination product	Amount (in mole)	Percent conversion	
		on C	on S
Hexafluorodimethyl ether	0.0643	16.2	—
Sulfuryl fluoride	0.1805	—	45.5
Pentafluorodimethyl ether	0.0912	23.0	—
Trifluoromethyl fluorosulfonate	0.1323	16.7	33.4
Tetrafluorodimethyl ether	0.0203	5.1	—
Hexafluorodimethyl sulfate	0.0531	13.4	13.4
Difluoromethyl fluorosulfonate	0.0213	2.7	5.3
	Total	77.1	97.6

EXPERIMENTAL

Electrolysis was carried out in a steel electrolytic bath with a square cross section, using a nickel anode and an iron cathode with plate form; the volume of the bath was 600 ml, the anode surface was 1200 cm^2.

A solution of 50 g of dimethyl sulfate in 500 ml of commercial liquid hydrogen fluoride was placed in the electrolytic bath and after cooling to 0-5° was submitted to electrolysis with a current strength of 7.5 a at a potential difference of 5 v. The gas which was evolved was passed successively through a reflux condenser cooled to −10°, a copper U-tube filled with 800 g of ignited potassium fluoride mixed with copper turnings, and was condensed in two successive traps cooled respectively to −78 and −100°. The gases which did not condense were passed through a column with phosphoric anhydride, a bottle full of glass beads, and an absorption flask with an acid solution of potassium iodide, and were collected in a gasometer.

During the electrolysis a colorless liquid condensed in the traps; elementary iodine was evolved at the bottom of the absorbing vessel, and hydrogen collected in the gasometer. At the end of the electrolysis the potential difference increased to 7 v, the current strength dropped to 5 a. Electrolysis was stopped with the appearance of crackling and flakes in the electrolytic bath. After passage of 382 ampere-hours we collected in both traps about 60 ml of condensate and in the gasometer about 163 liters of hydrogen. About 320 ml of reaction mixture remained in the electrolytic bath; the bottom of the bath, walls of the vessel, and cathode plate were covered with a green film.

The condensate was fractionated in a low temperature column and gave the following fractions, 1st, 28.5 g, b.p. −60° to −55°; 2nd, 12.4 g, b.p. −37 to −34°; 3rd, 22.2 g, b.p. −9 to −7°; 4th, 2.4 g, b.p. 3-5°; 5th, 15.6 g, b.p. 29-35° (total amount of transitional fractions was 4.1 g).

The 1st fraction was a gas which condensed in the form of a colorless liquid. With slow passage of the gas through a 10% aqueous solution of sodium hydroxide there was partial solution; the extra weight of the alkali solution was 18.4 g. The alkali insoluble preparation, 9.9 g, was hexafluorodimethyl ether with b.p. −60 to 59°.

Found M 156.0. C_2OF_6. Calculated M 154.0.

The gas soluble in alkali was sulfuryl fluoride.

Found (g): F 6.21; S 5.29. Calculated for 18.4 g SO_2F_2: F 6.65; S 5.77.

The 2nd fraction was pentafluorodimethyl ether, b.p. −36 to −35°.

Found: M 134.3. C_2HOF_5. Calculated: M 136.0.

The 3rd fraction was the trifluoromethyl ester of fluorosulfonic acid, b.p. −8.5 to −8°.

Found %: F 45.63. M 166.2. CO_3F_4S. Calculated %: F 45.25, M 168.1.

The 4th fraction was tetrafluorodimethyl ether, b.p. 4-5°.

Found: M 116.5. $C_2H_2OF_4$. Calculated: M 118.0.

The 5th fraction was a mixture, part of which reacted energetically with ice water with evolution of carbon monoxide (test with palladium chloride), and part formed an oily layer. The lower oily layer, 12.4 g, was separated and fractionated. It was a heavy, mobile liquid with b.p. 29.5-30°, d^{20}_4 1.7600, $n^{20}D$ 1.280, MR_D 23.38; calc. 23.33; and was hexafluorodimethyl sulfate.

Found %: C 10.54; F 48.22; S 13.36. M 230.8. $C_2O_4SF_6$. Calculated %: C 10.25; F 48.72; S 13.68. M 234.0.

Hexafluorodimethyl sulfate did not dissolve in water, aqueous alkali, and acids, liquid hydrogen fluoride; soluble in organic solvents.

In the water solution we determined the content of fluoride ion (thoriometry), sulfate ion (by weight method), and acidity (acidometry with phenolphthalein).

Found (g): F 1.25; S 0.66. Equiv. NaOH 0.111. Calculated for 3.2 g CHO_3SF_3 (g): F 1.22; S 0.68. Equiv. NaOH 0.107.

SUMMARY

1. We have studied the electrochemical fluorination of dimethyl sulfate and have obtained hexafluorodimethyl sulfate.

2. We have shown that electrochemical fluorination of esters can be carried out without destructive decomposition of the starting substance under conditions of optimum current density.

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FLUOROMETHYL ESTERS OF SULFURIC ACID

III. MONOFLUORODIMETHYL SULFATE

G. A. Sokol'skii and M. A. Dmitriev

In a previous communication [1] we considered the preparation of hexafluorodimethyl sulfate by the electrochemical fluorination of dimethyl sulfate. Here it was confirmed that among the reaction products we could not find partially fluorinated dimethyl sulfates, which was explained by their destruction during the process of electrolysis. According to present opinion [2] the basic factors which determine the destruction of fluorinated compounds are the amount and density of the current passed; here the composition of the electrolyte usually is a factor which affects only the conductivity of the system. However, such a limited role of the electrolyte composition is evidently not entirely correct. It is certain that the concentration of the fluorinated compound in the solution of hydrogen fluoride, or, more accurately, the ratio of the amounts of fluorinated compound and hydrogen fluoride should reflect on the composition of the product of fluorination. In the electrolysis of dilute solutions the possibility of exhaustive fluorination and destruction of the starting compound is very great. In the case of more concentrated solutions, that is, with a relative deficiency of hydrogen fluoride, the probability of formation of a completely fluorinated compound is decreased. Finally, in the electrolysis of a mixture of organic compounds with a small amount of hydrogen fluoride, it is possible obviously to isolate a product with a small degree of fluorination, down to monofluorosubstituted derivatives.

In order to obtain partly fluorinated compound, we studied the electrolysis of a mixture of dimethyl sulfate and a small amount of hydrogen fluoride, taken in the molar ratio 1 : 5.5. The other parameters of the electrolysis were: potential difference 6-8 v, anode current density 0.005 a/cm^2, temperature of electrolysis 0-5°. Under these conditions the composition of the fluorination product (see table) differed markedly from the composition of the product of electrolysis of dilute solutions of dimethyl sulfate in hydrogen fluoride as described earlier [1].

It was seen that in this case the chief product of the electrochemical fluorination of dimethyl sulfate was monofluorodimethyl sulfate. The structure of this compound was shown by the fact that when a sample of the preparation was boiled with aqueous alkali we found in the solution 1 equivalent of formaldehyde and 1 equivalent of fluoride ion.

$$CH_2F-O-SO_2-O-CH_3 + H_2O \rightarrow CH_2O + HF + CH_3-O-SO_2-OH$$

In considerably smaller amounts there were formed polyfluorinated dimethyl sulfates with different degrees of substitution, including hexafluorodimethyl sulfate. The processes of destruction of the sulfates leading to formation of fluorine substituted methyl esters of fluorosulfonic acids and sulfuryl fluoride were also not dominant.

Thus, comparing the composition of the product of electrochemical fluorination of dimethyl sulfate using dilute and concentrated solutions we can observe that depending on the ratio of amounts of fluorine compounds and hydrogen fluoride in the electrolyte the process of fluorination can be directed to the preparation of completely or partially fluorinated compounds. We have thus shown a new possibility of regulating the reaction of electrochemical fluorination. On the other hand, these results confirm the stepwise character of the process of electrofluorination.

EXPERIMENTAL

The electrolysis was carried out in a steel electrolytic bath with a square cross setion using a nickel anode and an iron cathode in the form of plates; the bath volume was 600 ml, the anode surface 1200 cm^2.

A mixture of 290 g of dimethyl sulfate and 250 g of commercial liquid hydrogen fluoride was placed in the electrolytic bath and after cooling to 0-5° was submitted to electrolysis with a current strength of 6 a and a potential

Production of fluorination	Amount		Conversion (in %)
	g	moles	
Sulfuryl fluoride	23.2	0.227	9.9
Trifluoromethyl fluorosulfonate	4.6	0.027	1.2
Hexafluorodimethyl sulfate	34.0	0.159	6.9
Difluoromethyl fluorosulfonate	18.6	0.124	5.4
Mixture of fluorinated sulfates	7.4	(0.055)	(2.4)
Monofluorodimethyl sulfate	189.2	1.315	57.1
	Sum	1.907*	82.9

* The amount of starting dimethyl sulfate was 2.301 moles.

difference of 6 v. The emerging gases were passed through a copper U-tube filled with 100 g of ignited potassium fluoride mixed with copper turnings, and were condensed in two successive traps cooled respectively to −78 and 100°. The noncondensed gases were passed through a column of phosphoric anhydride and were collected in a gasometer. During the electrolysis a colorless liquid condensed in the traps, and hydrogen collected in the gasometer. At the end of the electrolysis the potential difference increased to 8 v and the current strength fell to 3 a, after which the electrolysis was stopped. After the passage of 410 a- hours about 35 ml of condensate had collected in the traps and about 180 liters of hydrogen was found in the gasometer; the weight increase of the U-tube was about 25 g. In the electrolytic bath there remained 432 g of reaction mixture, a clear liquid with a light yellow color. No corrosion of the body of the electrolytic bath or the electrodes occurred.

The condensate was fractionated in a low temperature column and gave the following fractions.

1st, 25.5 g, b.p. −60 to −53°; 2nd, 4.6 g, b.p. −9 to −7°; 3rd, 2.2 g, b.p. 3-5°; 4th, 8.3 g, b.p. 29-35° (total amount of transitional fractions 1.5 g).

The 1st fraction was evaporated and slowly passed through 10% aqueous sodium hydroxide in the gaseous form; it dissolved almost completely, the increase in weight of the alkali solution was 23.2 g. We determined the fluorine content in the solution by the argentometric process (through lead fluorochloride) and the sulfur content by the weight method (precipitation by barium chloride after long boiling of the acidified solution). The dissolved gas was sulfuryl fluoride.

Found (g): F 8.49; S 7.03; calculated for 23.2 g SO_2F_2: F 8.65 g; S 7.29 g.

The 2nd fraction was trifluoromethyl fluorosulfonate [3] with b.p. −8.5 to −8°.

Found: M 170.4. CO_3SF_4. Calculated: M 168.1.

The 3rd fraction was tetrafluorodimethyl ether with b.p. 4-5.5°.

Found: M 119.6. $C_2H_2OF_4$. Calculated: M 118.0.

The 4th fraction was a mixture of substances from which washing with water separated 5.2 g of hexafluorodimethyl sulfate with b.p. 29.5-30° and d^{20}_4 1.7605. In the water solution we determined the content of fluoride ion (thoriometry), sulfate ion (weight method), and acidity (acidometry with phenolphthalein). The component which dissolved was difluoromethyl fluorosulfonate (3.0 g).

Found: F 1.18 g; S 0.59 g 0.102 equiv. NaOH. Calculated for 3.0 g CHF_2OSO_2F: F 1.14 g; S 0.64 g; 0.100 equiv. NaOH.

The reaction mixture which was left in the electrolytic bath was treated by different processes, A and B.

A. The reaction mixture, 216 g, was kept at 80° in a copper vessel for four hours; the gaseous product which separated was passed through a copper U-tube filled with 250 g of ignited potassium fluoride mixed with copper turnings and heated to 100°; it was condensed in a trap cooled to −20°. The increase in weight of the U-tube was 70 g; 13.0 g of liquid condensate collected in the trap; the rest of the reaction mixture was a dark yellow liquid weighing 128.1 g.

The condensate was fractionated and gave the following fractions. 1st, 12.5 g, b.p. 29-35°; 2nd, 0.4 g, b.p. 35-57°.

The 1st fraction was a mixture of substances from which washing with water gave 9.0 g of hexafluorodimethyl sulfate; in the water solution there was 3.4 g of difluoromethyl fluorosulfonate. The second fraction was a mixture of fluorine containing sulfates and was not studied in detail.

To the rest of the reaction mixture, cooled to −20°, was added in 2-3 g portions with shaking 50 g of powdered ignited potassium fluoride. Then the mixture was fractionated, first at atmospheric pressure, and then at reduced pressure, and the following fractions were isolated.

1st, 8.7 g, b.p. 29-35°, 2nd, 3.3 g, b.p. 42-95°; 3rd, 92.8 g, b.p. 115-122° (106 mm); residue, 72.6 g, in the form of a black powder.

The 1st fraction was a mixture of 4.2 g of hexafluorodimethyl sulfate and 4.4 g of difluoromethyl fluorosulfonate. The 2nd fraction was colorless liquid with a sharp, irritating odor and was a mixture of fluorine containing sulfates.

Found %: F 39.7; S 26.5, d^{20}_4 1.4150.

The 3rd fraction was a colorless, mobile liquid with a sharp odor and was monofluorodimethyl sulfate.

B.p. 180-181° (760 mm), 119-120° (106 mm), 104° (68 mm), 75° (18 mm), d^{20}_4 1.4002, n^{20}_D 1.3790.

Found %: C 16.24; H 3.65; F 13.40; S 22.89. M 141.8; MR_D 23.41. $C_2H_5O_4FS$. Calculated %: C 16.65; H 3.47; F 13.20; S 22.20. M 144.1; MR_D 23.20.

Monofluorodimethyl sulfate was not soluble in water, but dissolved easily in organic solvents. When a sample of the preparation was boiled with 1 N sodium hydroxide, we found in the solution 0.96 equivalents of formaldehyde (iodometrically) and 1.04 equivalents of fluoride ion (thoriometry).

B. The reaction mixture, 216 g, was treated slowly with stirring with 250 g of ice. The heavy oil which separated was dried over magnesium sulfate and fractionated. In the fractionation of 126.5 g of oil the following fractions were separated: 1st, 14.4 g, b.p. 29-30°, which was hexafluorodimethyl sulfate; 2nd, 1.7 g, b.p. 40-98°, a mixture of fluorine containing sulfates; 3rd, 94.6 g, b.p. 119-120° (106 mm), which was monofluorodimethyl sulfate.

SUMMARY

1. We have studied the electrolysis of a mixture of dimethyl sulfate and hydrogen fluoride (mole ratio 1 : 5.5) and obtained monofluorodimethyl sulfate.

2. We have showed that depending on the ratio of the amount of fluorinated compound and hydrogen fluoride the process of electrolytic fluorination can be directed toward either complete or partial fluorination of the compound.

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THE SYNTHESIS OF SOME ORGANIC COMPOUNDS LABELED
WITH DEUTERIUM AND OXYGEN ISOTOPE O[18]

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In the present paper we describe methods by which, in the Institute of Physical Chemistry, Academy of Sciences, UkrSSR we have carried out the synthesis of a series of organic compounds labeled with deuterium or O^{18} in determined positions in the molecules. These methods are based on known reactions. They permit obtaining labeled compounds simply, in most cases with good yields, and without marked dilution by heavy isotopes.

EXPERIMENTAL

Acetic acid, CD_3COOD.

$$CH_2(COOH)_2 + 4D_2O \rightarrow CD_2(COOD)_2 + 4HDO$$
$$CD_2(COOD)_2 \xrightarrow{140-145°} CD_3COOD + CO_2$$
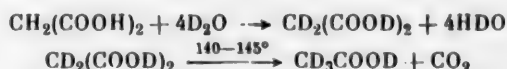
One hundred g of dry malonic acid was heated for one hour at 80° with 75 g of D_2O. The water was then distilled off in a vacuum. If it was necessary to obtain a substance with a high content of deuterium, the exchange was repeated 3-4 times. The distilled heavy water was used for obtaining further portions of deuteromalonic acid.

The deuteromalonic acid $CD_2(COOD)_2$ in a Wurtz flask with a thermometer dipping almost to the bottom and a condenser was heated on an oil bath to 140-145°. Decarboxylation of 100 g of malonic acid with simultaneous distillation of the deuteroacetic acid lasted about one hour. The resulting distillate after repeated distillation boiled in the range 105-116°, m.p. 6-7°. Yield 58-60%, that is calculated on anhydrous acetic acid, about 90%. The product contained 3-7% water. The deuterium content was the same as in the starting malonic acid.

Ethyl bromide, C_2D_5Br.

As the basis for the synthesis we took the method for obtaining C_2H_5Br from hydrogen bromide and ethylene with a catalyst of aluminum bromide [1].

$$P + 3D_2O + 3Br \rightarrow 3DBr + D_3PO_3$$
$$CD_2Br·CD_2Br + Zn \rightarrow CD_2=CD_2 + ZnBr_2$$
$$CD_2·CD_2 + DBr \xrightarrow{AlBr_3} CD_3CD_2Br$$
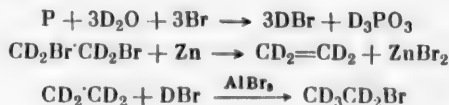
In a Wurtz flask we placed 15.5 g (0.5 g-atom) of dry red phosphorus and 29 g (1.45 mole) of D_2O, and from a dropping funnel we gradually added 120 g of dry bromine. The DBr which formed was freed from bromine in a tube filled with glass beads, mixed with 2 g of phosphorus and 1 g of D_2O and dried with calcium chloride ignited in a vacuum at 400°. The gas was then passed through a bubble counter with nitrobenzene and into the reaction vessel shown in Fig. 1, into which was introduced with somewhat lower speed 30 liters of heavy ethylene from a gasometer.* In the reaction vessel we first placed 10 g of anhydrous aluminum bromide and 6 g of ethyl bromide, and immersed the vessel in a mixture of dry ice and alcohol. The rate of the gas stream should be such that it had time to react. This could be determined by the almost complete absence of gas passing through the reaction vessel. Ice was added

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* The heavy ethylene was obtained from $C_2D_4Br_2$ [2], with this difference, that before treatment of the dibromide with zinc it was purified by fractionation.

to the reaction product and it was also cooled from the outside; it was washed with water, with soda solution, again with water, and it was dried with calcium chloride. Yield 92 g; subtracting the amount of ethyl bromide added this is 86 g, that is, 60% with respect to the ethylene taken. Fractionation gives 88 g of substance with b.p. 38-38.5° (760 mm). The deuterium content in it was 6-7% less than in the starting C_2D_2.

Ethyl alcohol, C_2D_5OD.

$$2C_2D_5Br + Ag_2O + D_2O \longrightarrow 2C_2D_5OD + 2AgBr$$

In a sealed ampule we heated 11.4 g (0.1 mole) of C_2D_5Br, 11.6 g (0.05 mole) of silver oxide* and 10 g of D_2O at 100° for 15 hr. The liquid was distilled in a vacuum into a trap cooled by liquid air, the distillate was saturated with anhydrous potash and fractionated. The fraction with b.p. 78-78.5° (760 mm) was again distilled over a small amount of potash. The yield of alcohol with b.p. 78-78.5° (760 mm) was 3.5 g, which was 67% with respect to the ethyl bromide taken. The deuterium content was 2-3% less than in the starting C_2D_5Br. The alcohol contained 4-5% water. The residue after distillation of the alcohol contained heavy water with almost unchanged isotope composition, and this could be completely separated by vacuum distillation.

Ethyl alcohol, CD_3CH_2OH.

$$CD_3COOD \xrightarrow{LiAlH_4} CD_3CH_2OH$$

To 200 ml of an ether solution of 9.4 g (0.25 mole) of lithium aluminum hydride, filtered and heated to boiling, obtained in the usual way from lithium hydride and aluminum bromide and placed in a flask with a reflux condenser, dropping funnel, and stirrer, we added dropwise with energetic mixing during two hours 100 ml of an ether solution of 11.1 g (0.173 mole) of acetic acid CD_3COOD. At the end of addition of acetic acid heating and stirring were continued for 0.5 hr more, after which the mixture was treated with 50 ml of water, 300 ml of 10% sulfuric acid, and was stirred for a further 1.5 hr. The water layer which separated was distilled in a column and fractions were collected: 1st, 77-82° (about 8 g), 2nd 82-100° (10 g). The 2nd fraction was saturated with potash and the upper layer which formed was combined with the 1st fraction, boiled with 0.5 g of anhydrous potash, and distilled. Yield of alcohol with b.p. 77.5-78.5° (760 mm) 8 g (93%); the alcohol contained 4-5% water. The deuterium content in its methyl group was 75-85% of the content in the methyl group of the starting acetic acid.
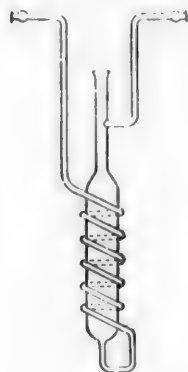
Ethyl alcohol $C_2H_5O^{18}H$.

$$2C_2H_5I + Ag_2O + H_2O^{18} \longrightarrow 2C_2H_5O^{18}H + 2AgI$$

Fig. 1.

In a sealed glass ampule was heated 15.6 g (0.1 mole) of ethyl iodide, 11.6 g (0.05 mole) of silver oxide and 9.0 g of H_2O^{18} at 100° for 10 hr. While heating, the ampule was vigorously shaken four or five times. The liquid from the ampule was then distilled in a vacuum into a trap cooled with liquid air. For isolation of the alcohol, the combined distillates from ten ampules were saturated with 90 g of anhydrous potash and distilled. The fraction with b.p. 75-80° was again distilled over 3 g of potash. The yield of alcohol with b.p. 78-78.5° (760 mm) was 30 g, that is, 65% with respect to the ethyl iodide used in the reaction. The alcohol contained 4-5% water; it could be dehydrated in the usual way. The extra content of O^{18} was 70-75% of the extra O^{18} in the starting water.

Methyl alcohol $CH_3O^{18}H$.

$$2CH_3I + Ag_2O + H_2O^{18} \longrightarrow 2CH_3O^{18}H + 2AgI$$

This substance was obtained in the same way as $C_2H_5O^{18}H$ by heating at 100° for eight hr 14.2 g (0.1 mole) of methyl iodide, 11.6 g (0.05 mole) of silver oxide, and 9.0 g of H_2O^{18}, saturating the combined distillates from ten ampules with 100 g of potash and distilling repeatedly over 2 g of potash for the fraction with b.p. 63-67°. The yield of alcohol with b.p. 63.5-64.3° (756 mm) was 12 g (38%). The excess content of O^{18} was 70-75% of its excess in the starting water.

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*Silver oxide was prepared not more than a day before use and was dried in the cold by washing with alcohol, ether, and then removing them in a vacuum.

The aqueous fraction with b.p. 98-100° obtained in the isolation of $CH_3O^{18}H$ and $C_2H_5O^{18}H$ was almost pure H_2O^{18} and contained only 20% less O^{18} than the starting water. This waste product could be purified and used again.

Introduction of deuterium into hydrocarbons. Hydrocarbons were obtained by decomposition of the corresponding Grignard reagents with deuterium oxide. In the usual method we introduced small changes: for obtaining the Grignard compound we used less ether than usual so as to lessen the isotope dilution by water contained in the ether; decomposition of the Grignard reagent was carried out by ether saturated with D_2O [3] in the apparatus shown in Fig. 2: flask (1) with the reagent was heated on a water bath; after the ether condensed in the condenser it passed through a layer of heavy water in the test tube (2) and returned to flask (1) saturated with D_2O. This treatment with water avoided formation of lumps in the reaction mixture, so that the heavy water was used almost completely.

Benzene C_6H_5D.

$$C_6H_5MgBr + D_2O \longrightarrow C_6H_5D + Mg(OD)Br$$

The Grignard reagent obtained from 24.3 g (1 g-atom) of magnesium, 157 g (1 mole) of bromobenzene, and 600 ml of ether was decomposed with 20.5 g of D_2O. The ether was slowly distilled off in a fractionating column. The residue of ether and benzene was distilled completely from the solid at 100-120° in a vacuum; the distillate was fractionated over metallic sodium. Yield of benzene 53 g(68%), b.p. 80-81° (765 mm), $n^{20}D$ 1.5018, deuterium content 16.0-16.5 at.%.

Toluene $C_6H_5CH_2D$.

$$C_6H_5CH_2MgCl + D_2O \longrightarrow C_6H_5CH_2D + Mg(OD)Cl$$

This was obtained in the same way as benzene C_6H_5D from 24.3 g (1 g-atom) of magnesium, 126.6 g (1 mole) of benzyl chloride, 450 ml of ether, and 20.5 g of D_2O. Yield 58 g (63%), b.p. 109.5-110.5° (753 mm), $n^{20}D$ 1.4970, deuterium content 11.6-12.0 at.%.

Ethane C_2D_6.

$$C_2D_5MgBr + D_2O \longrightarrow C_2D_6 + Mg(OD)Br$$

The Grignard reagent obtained from 2.4 g (0.1 g-atom) of magnesium, 11.4 (0.1 mole) of ethyl bromide, C_2D_5Br, and 75 ml of ether was decomposed with 2.2 g of D_2O. The heavy ethane which formed was separated from the vapors of ether in a condenser cooled with tap water and in two traps filled with a mixture of dry ice and acetone, and was collected in a gasometer over water. Yield 2.3 liters. Deuterium content 3-4% less than in the starting ethyl bromide.

Fig. 2. Explanation in text.

Triphenylmethane $(C_6H_5)_3CD$.

$$(C_6H_5)_3CMgCl + D_2O \longrightarrow (C_6H_5)_3CD + Mg(OD)Cl$$

The Grignard reagent was prepared by the method of [4] from 14.0 g (0.58 g-atom) of magnesium, 42.0 g (0.15 mole) of triphenylmethyl chloride, 4.5 g of iodine, and 600 ml of ether, and was decomposed with 3.3 g of D_2O. The ether solution of triphenylmethane was separated from the magnesium precipitate and its salts by filtration; it was evaporated dry and the residue was dissolved in 300 ml of benzene and decolorized by boiling with activated charcoal. The benzene was distilled off to beginning of crystallization and the crystals of the compound $(C_6H_5)_3CD \cdot C_6H_6$ which precipitated on cooling were dried at 50° to remove all the benzene. Yield of triphenylmethane 28 g, m.p. 93-94°. From the mother liquor we could isolate about 2 g more of substance with m.p. 91-92°. Total yield 78%. Deuterium content 5.2-5.5 at.%.

α-Deuteronaphthalene.

$$\alpha\text{-}C_{10}H_7MgBr + D_2O \longrightarrow \alpha\text{-}C_{10}H_7D + Mg(OD)Br$$

The Grignard reagent prepared from 24.3 g (1 g-atom) of magnesium, 20.7 g (1 mole) of α-bromonaphthalene* and 450 ml of ether was decomposed with 20 g of D_2O. The ether was distilled off in a weak current of steam and then

* The commercial preparation was purified from naphthalene by two vacuum distillations. In each distillation we discarded about 15% of the volume of substance taken. In the experiments we used the fraction with b.p. 153.8-154.8° (32 mm).
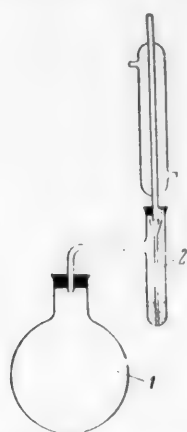
the receiver was changed and the deuteronaphthalene was steam distilled. Yield of crude product 121 g (94.5%), m.p. 77-78.5°. After recrystallization from alcohol, m.p. 79.5-80.5°. Deuterium content 11.6-11.8 at.%.

Formic acid.

In the synthesis of deuteroformic acid we started from oxalic acid $(COOD)_2$,which was obtained by dissolving the anhydrous acid $(COOH)_2$ in heavy water with heat and distillation of the water in a vacuum. For full replacement of hydrogen by deuterium this operation was repeated 3-4 times.

Acid DCOOD.

$$(COOD)_2 \longrightarrow DCOOD + CO_2$$

A wide-necked, round-bottomed flask with the oxalic acid was connected through a ground glass connection with a quartz tube (length 600 mm, diameter 25 mm) filled with glass fragments and was heated to 350-360°. The outlet of the quartz tube was connected to two traps immersed in liquid air. Then a 1-5 mm discharge was created in the system and the flask with the oxalic acid was heated to 190-210°. The formic acid formed by the decomposition of the oxalic acid vapors in the quartz tube was collected in the traps. It distilled in the range 101-105°, contained as much deuterium as was in the oxalic acid, and 4-6% water of the same isotopic composition. Yield 83-87%. When oxalic acid not completely converted with deuterium was used for the synthesis, the product contained about 10% less C-D bonds, and in the O-D bonds there was about 10% more deuterium than in the oxalic acid.

Acid DCOOH.

$$2DCOONa + (COOH)_2 \longrightarrow 2DCOOH + (COONa)_2$$

We ground 69 g (1.0 mole) of anhydrous sodium formate obtained from DCOOD in a mortar with 45 g (0.5 mole) of anhydrous oxalic acid $(COOH)_2$ and heated for one hour at 100° in a flask with a reflux condenser. The formic acid was distilled in a vacuum into a trap cooled with liquid air, first at 30-40 mm, and when distillation slowed down, at 1-2 mm and heating to 100°. This operation lasted five to six hours. The acid which was obtained was distilled. The yield of the fraction with b.p. 100.7-102.0° was 42.3-44.7 g (90-95%). The deuterium content was the same as in the starting formate.

Acid HCOOD

$$2HCOONa + (COOD)_2 \longrightarrow 2HCOOD + (COONa)_2$$

This was obtained in the same way as DCOOH, from ordinary sodium formate and oxalic acid $(COOD)_2$ and contained an admixture of about 0.5% DCOOD.

Formaldehyde D_2CO (water solution).

$$(DCOO)_2Zn \xrightarrow{\ 280-300°\ } D_2CO + CO_2 + ZnO$$

Twenty g of anhydrous zinc formate $(DCOO)_2Zn$, obtained by neutralizing a water solution of DCOOD with zinc oxide and drying at 150°, was heated at 280-300° in a bath of Wood's metal in a vacuum at a pressure of 1-5 mm in a Wurtz flask connected with three traps. The first trap served to remove dust; in the second and third, cooled by liquid air, we collected the cracking products. After two hours the temperature rose in 15 min to 350° and heating was discontinued, while evacuation was continued until the flask had cooled. The second and third traps were then carefully warmed to room temperature to evaporate carbon dioxide and then the contents of the third trap were distilled in a vacuum into the second, which was cooled with liquid air. At the end of the distillation, the third trap was heated to 120-130° for depolymerization of the paraform which had been formed. To the cracked product collected in the second trap we added 2.5 ml of water, neutralized the solution with sodium bicarbonate, and distilled in a vacuum, cooling the receiver with liquid air. At first distillation took place at room/temperature, and finally at 120-130°. The distillate contained flakes of paraform. To obtain a clear solution, we added to the distillate 2-3 drops of 0.3 N sulfuric acid and again distilled almost to dryness in a stream of air. The receiver was cooled with liquid air. The yield of clear, neutral solution was 3.5-4.0 ml. The formaldehyde content in the solution was 18-20%,which corresponded to 17-20% of the theoretical yield. The resulting formaldehyde contained as much deuterium as in the starting zinc formate.

Heavy polyethylene.*

$$C_2D_2 \xrightarrow[\text{TiCl}_4]{R_3Al} (C_2D_2)_n$$
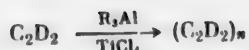
Heavy polyethylene was obtained by polymerization of deuteroethylene. The synthesis of the latter was reported above.

In a four-necked flask fitted with a rapid stirrer, reflux condenser, thermometer, and glass tube dipping to the bottom, we placed 250 ml of dry benzine which contained no unsaturated compounds ("Kalosha" benzine); air was replaced in the flask by dry nitrogen, free from oxygen, the liquid was heated to 50° and to it in a stream of nitrogen was added 20 ml of a 7% solution of aluminum triisobutyl in "Kalosha" benzine and 2 ml of titanium tetrachloride. Then from a gasometer we passed into the flask 36 liters of pure, dry deuteroethylene, with energetic stirring. The rate of passing the ethylene was 25 liters/hour. The temperature of the reaction mixture then rose spontaneously to 65-72°. The gas which did not react was collected in a gasometer. Its amount reached 4 liters.

The ethylene, before passage into the reactor was freed from oxygen in a tube filled with copper turnings heated to 400-450°, and from carbon dioxide and moisture with calcium chloride, ascarite, and phosphorus pentoxide.

At the end of the polymerization we added gradually with stirring and in a stream of nitrogen 200 ml of dry isopropyl alcohol, and continued stirring for 45 min. The heavy polyethylene was separated by filtration, washed three times with isopropyl alcohol, twice with water, and was dried at 65-75°. Yield 35 g, that is, 82% with respect to the ethylene reacting. Deuterium content 92 at.%. The starting deuteroethylene contained 96 at.% deuterium.

SUMMARY

We have described easily reproducible methods for obtaining the following labeled compounds: deuteroacetic acid CD_3COOD, ethyl bromide C_2D_5Br, ethyl alcohols C_2D_5OD and CD_3CH_2OH, deuterobenzene C_6H_5D, deuterotoluene $C_6H_5CH_2D$, hexadeuteroethane, triphenyldeuteromethane, α-deuteronaphthalene, deuteroformic acids DCOOD, DCOOH, and HCOOD, formaldehyde D_2CO, and deuteropolyethylene, and also methyl and ethyl alcohols labeled with the oxygen isotope O^{18}.

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A STUDY OF THE NATURE OF THE CARBON-METAL BOND
BY THE METHOD OF ISOTOPE EXCHANGE

II. EXCHANGE OF PHENYL GROUPS

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In previous work [1] we studied the exchange of ethyl groups among ethyl metals. In the present paper we give results on exchange of phenyl groups between metalloorganic compounds of mercury, silicon, tin, lead, sodium, magnesium, and aluminum, for which we have used compounds containing phenyl labeled with C^{14}.

The results of the work are given in the table. The percent exchange was calculated with neglect of changes in molar ratio of substances which occurred because of partial decomposition in the exchange.

The table shows that as in the case of the ethyl metals [1], tetraphenyl lead is much less able to exchange than is diphenyl mercury. It is interesting that in the system tetraphenyl lead + diphenyl mercury the exchange reaches on the average 88% in 20 hr at 150°, while in the corresponding system diethyl mercury + tetraethyl lead there was no exchange [1].

On the basis of the data of the table we can say that in the elements of group IV which we studied the mobility of the phenyl group increases with increasing atomic number of the element. In respect to stability of the bond metal-phenyl the elements can be arranged in the order Si > Sn > Pb.

All the phenyl metals which we studied can be arranged according to their ability to exchange phenyl groups in the following order:

$$Hg(C_6H_5)_2 > Pb(C_6H_5)_4 \geqslant Al(C_6H_5)_3 > Sn(C_6H_5)_4 > NaC_6H_5 > Si(C_6H_5)_4.$$

Phenylmagnesium bromide drops out of this series, since it exchanges only with diphenyl mercury, but the exchange in this case is sufficiently great (56.9%).

EXPERIMENTAL

I. Syntheses of Substances Labeled with C^{14}

Bromobenzene was synthesized by the usual method of brominating benzene labeled with C^{14} in the presence of iron filings. The activity of the resulting preparation (two syntheses) was 663 and 636 μCu/mole.

Diphenyl mercury was obtained by the method of Gilman and Brown [2] with slight modifications: Instead of the Soxhlet apparatus for extraction we used a cylindrical funnel with a joining tube between the wide and narrow parts. In this funnel extractor we placed a cylindrical funnel with a glass filter on which the mercury dichloride was put. This was more suitable than a Soxhlet apparatus since it could be regulated by addition of mercuric chloride to the reaction mixture. From two syntheses we obtained preparations with activities 1159 and 983 μ Cu/mole.

Sodium phenyl was obtained from labeled diphenyl mercury with metallic sodium in an open apparatus under nitrogen by the method of Gilman and co-workers [3]. Its activity was calculated on the activity of the starting diphenyl mercury.

Triphenyl aluminum was synthesized by the method of Nesmeyanov and Novikova [4]. The preparations obtained from two syntheses had activities of 1253 and 1690 μCu/mole.

System (second component labeled with C^{14})	Experimental conditions			Initial activity of second component (in μ Cu/mole)	Activity of first component after experiment		Exchange (in %)	Remarks
	Mole ratio of substances	Temperature	Time (in hours)		In μCu/mole	In % of initial		
Tetraphenyl silicon + sodium phenyl*	1 : 2	100°	5	491.5	9.1	0.93	1.4	
Tetraphenyl tin + sodium phenyl*	1 : 2	100	5	491.5	64.3	6.5	9.8	
Tetraphenyl lead + sodium phenyl*	1 : 2	100	5	491.5	37.4	3.8	5.7 }	Average
	1 : 2	100	5	579.5	13.4	1.2	1.7 }	3.7 ± 2%
Diphenyl mercury + sodium phenyl*	1 : 1	100	5	491.5	–	–	–	Diphenyl-
	1 : 1	50	5	491.5	–	–	–	mercury could not
Tetraphenyl silicon + phenyl-magnesium bromide**	1 : 4	100	5	636	1.7	~ 0.07	~ 0.1	be isolated from the
Tetraphenyl tin + phenyl-magnesium bromide**	1 : 8	100	5	636	5.0	~ 0.1	~ 0.3	mixture
Tetraphenyl lead + phenyl-magnesium bromide**	1 : 4	100	5	636	None	None	None	
Diphenyl mercury + phenyl-magnesium bromide**	1 : 2	100	5	663	378	29.9	57.0	
Tetraphenyl silicon + diphenyl mercury	1 : 2	150	20	1159	0.7	~ 0.03	~ 0.06	
Tetraphenyl tin + diphenyl mercury	1 : 2	150	20	1159	124.8	5.4	10.8	
Tetraphenyl lead + diphenyl mercury	1 : 2	150	20	1159	976.3	42.1	84.2 }	Average
	1 : 2	150	20	1159	1063	45.9	91.7 }	88 ± 4%
Tetraphenyl silicon + triphenyl aluminum*	3 : 2	100	5	1253	Trace		Trace	
Tetraphenyl tin + triphenyl aluminum*	3 : 2	100	5	1253	2.9	0.3	0.5	
Tetraphenyl lead + triphenyl aluminum*	3 : 4	100	5	1690	125.8	5.6	11.0	
Diphenyl mercury + triphenyl aluminum*	3 : 2	100	5	1690	514.8	45.7	91	

*To a mixture of the solid substances we added benzine (3 ml) free from unsaturated compounds.

**Solution in ether.

Phenylmagnesium bromide was synthesized directly before the experiment from labeled bromobenzene and magnesium in ether.

All the substances (labeled with C^{14} and unlabeled) used in the present work were carefully purified and had constants which agreed with the literature. Later crystallizations were always carried out from petroleum ether free of unsaturated compounds.

II. Exchange Experiments

The exchange experiments were carried out by the method described previously [1] except in some cases, shown in the table, where solvents were used. Separation of mixtures of stable metalloorganic compounds was carried

our by recrystallization from suitable solvents until preparations were obtained with constant melting points which agreed with the substances before the experiment, and with unchanging activity. As shown above, later crystallizations were from petroleum ether free of unsaturated compounds.

Combustion of the metalloorganic compounds, preparation of samples of barium carbonate, and measurement of the activity (accuracy 1-2%) were carried out as described before [5]. The barium carbonate samples obtained from labeled substances before the exchange (second components in the table) served as standards for the samples obtained from the first components after the exchange.

We express thanks to E. M. Panov for preparing the samples of tetraphyl silicon, tetraphenyl tin, and tetraphenyl lead.

SUMMARY

1. On the basis of experiments on exchange of the phenyl group in 15 systems, each of which consisted of two metalloorganic compounds, we have found that the substances studied can be arranged in the following order of ability to exchange:

$$Hg(C_6H_5)_2 > Pb(C_6H_5)_4 \geqslant Al(C_6H_5)_3 > Sn(C_6H_5)_4 > NaC_6H_5 > Si(C_6H_5)_4.$$

2. We have found that as to stability of the metal-phenyl bond, the elements of group IV can be arranged in the order Si > Sn > Pb.

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THE SYNTHESIS OF NEW DERIVATIVES
OF 1,3,4-OXADIAZOLE

A. P. Grekov and E. P. Nesynov

In order to develop the previous work [1-3] on the study of new scintillation materials, we have synthesized a series of undescribed derivatives of 1,3,4-oxadiazole of the type:

$$R-\underset{O}{\overset{N-N}{|\!|\quad|\!|}}-R'$$
R = p-CH$_3$C$_6$H$_4$, p-CH$_3$OC$_6$H$_4$, p-ClC$_6$H$_4$, p-O$_2$NC$_6$H$_4$, α-C$_{10}$H$_7$; R' = α- and β-pyridyl.
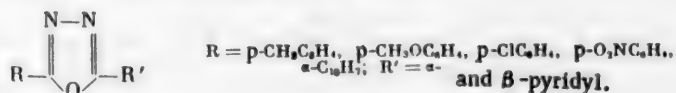
The synthesis of these compounds was carried out by the method developed earlier [4, 5] which consists in reaction of equimolecular amounts of carboxylic acid hydrazides with the corresponding acid chlorides in pyridine solution. The resulting diaroylhydrazines were treated with phosphorus oxychloride and the resulting product underwent cyclization by the action of water to the corresponding oxadiazole. The separation of the oxadiazoles which formed from water solution, in which their hydrochlorides were well soluble, was carried out by neutralization of the reaction mass with ammonia or diethylamine; they were purified by crystallization from different solvents or by chromatography.

All the oxadiazoles and hydrazides obtained in the present work were colorless, crystalline substances, soluble in organic solvents; they formed salts in acids which were easily soluble in water; when heated with aqueous solutions of mineral acids they were quickly hydrolyzed with formation of the starting diaroylhydrazines.

EXPERIMENTAL

The Synthesis of 2-(p-Tolyl)-5-(β-pyridyl)-1,3,4-oxadiazole.
  1-(p-Toluoyl)-2-(β-pyridoyl)hydrazine. We dissolved 22.2 g of the hydrazide of β-pyridinecarboxylic (nicotinic) acid [6] with heat in 300 ml of dry pyridine and with good stirring added gradually to the resulting mixture 30 g of p-toluic acid chloride. The resulting mass was stirred for 1.5 hr after which it was poured into 3 liters of distilled water; the reaction product which precipitated was filtered off, washed with water, and dried. Yield 27.5 g (67%), m.p. 200-201°. After recrystallization from ethanol with later chromatographic purification on aluminum oxide, m.p. 201-202°

  Found %: N 16.66. C$_{14}$H$_{13}$O$_2$N$_3$. Calculated %: N 16.47.

  2-(p-Tolyl)-5-(β-pyridyl)-1,3,4-oxadiazole. We mixed 22 g of 1-(p-toluoyl)-2-(β-pyridoyl)hydrazine with 100 ml of phosphorus oxychloride and boiled the resulting mass under reflux for 1.5 hr. Then, with good cooling and stirring, the contents of the flask were slowly poured into 0.5 liter of distilled water, neutralized with concentrated ammonia (355 ml) to a neutral reaction to litmus, the oxadiazole which precipitated was filtered off, washed with water, and dried. Yield 16.6 g, m.p. 122-123°. After recrystallization from dioxane and chromatographic purification on aluminum oxide, m.p. 127.5-128°. Yield 10 g (62%).

  Found %: N 17.46. C$_{14}$H$_{11}$ON$_3$. Calculated %: N 17.22.

Synthesis of 2-(p-Methoxyphenyl)-5-(β-pyridyl)-1,3,4-oxadiazole.
  1-(p-Methoxybenzoyl)-2-(β-pyridoyl)hydrazine. To a solution of 16 g of the hydrazide of p-methoxybenzoic acid [7] in 100 ml of anhydrous pyridine was added with stirring 17.5 g of β-pyridine carboxylic acid chloride hydrochloride. After two hours the reaction mass was poured into 1.2 liters of distilled water, the colorless product which

precipitated was filtered off, washed with water, and dried. Yield 23.2 g (88%), m.p. 178.5-179°. After recrystallization from dioxane and chromatographic purification, m.p. 180.5-181°.

Found %: N 15.45. $C_{14}H_{13}O_3N_3$. Calculated %: N 15.49.

2-(p-Methoxyphenyl)-5-(β-pyridyl)-1,3,4-oxadiazole. A mixture of 20 g of 1-(p-methoxybenzoyl)-2-(β-pyridoyl)hydrazine and 100 ml of phosphorus oxychloride was boiled for four hours. Then, with cooling, the reaction mass was poured into 0.5 liter of water, neutralized with concentrated ammonia (390 ml); the precipitate was filtered off, washed with water, and dried. After recrystallization from ethanol and benzene with later chromatographic purification of its dioxane solution on aluminum oxide, m.p. 173.5-174.5°. Yield 8.4 g (45%).

Found %: N 16.69. $C_{14}H_{11}O_2N_3$. Calculated %: N 16.60.

Synthesis of 2-(p-Chlorophenyl)-5-(β-pyridyl)-1,3,4-oxadiazole

1-(p-Chlorobenzoyl)-2-(β-pyridoyl)hydrazine. We dissolved 41 g of the hydrazide of β-pyridinecarboxylic acid [6] with heat in 550 ml of anhydrous pyridine and to the resulting mixture added 52.4 g of p-chlorobenzoic acid chloride. Then the reaction mass was poured into 2.2 liters of water and the precipitate was filtered off, washed with water, and dried. After recrystallization from dioxane and chromatographic purification, m.p. 211-212°. Yield 44.8 g (55%).

Found %: N 15.05. $C_{13}H_{10}O_2N_3Cl$. Calculated %: N 15.21.

2-(p-Chlorophenyl)-5-(β-pyridyl)-1,3,4-oxadiazole. We boiled 38.8 g of 1-(p-chlorobenzoyl)-2-(β-pyridoyl)hydrazine and 200 ml of phosphorus oxychloride for 2.5 hr. After cooling, the resulting mixture was carefully poured into 1 liter of water, neutralized with concentrated ammonia (630 ml) to litmus, and the precipitate was filtered off, washed with water, dried, and recrystallized from ethanol with addition of 10 ml of diethylamine. Yield 8.5 g (23%), m.p. 160-161°. After chromatographic purification of its benzene solution on aluminum oxide, m.p. 164-165°.

Found %: N 16.61. $C_{13}H_8ON_3Cl$. Calculated %: N 16.31.

Synthesis of 2-(p-Nitrophenyl)-5-(β-pyridyl)-1,3,4-oxadiazole

1-(p-Nitrobenzoyl)-2-(β-pyridoyl)hydrazine. Twenty-five g of the hydrazine of p-nitrobenzoic acid [7] was dissolved with heating in 250 ml of anhydrous pyridine and to the resulting mixture was added 25 g of β-pyridinecarboxylic acid chloride hydrochloride. Then to the reaction mass was added 2 liters of water, the precipitate was filtered off, washed with water, and dried. Yield 30 g (76%), m.p. 249-250°. After several recrystallizations from dioxane, m.p. 260-261°.

Found %: N 19.69. $C_{13}H_{10}O_4N_4$. Calculated %: N 19.58.

2-(p-Nitrophenyl)-5-(β-pyridyl)-1,3,4-oxadiazole. Ten g of 1-(p-nitrobenzoyl)-2-(β-pyridoyl)hydrazine and 50 ml of phosphorus oxychloride were boiled for four to five hours. Then most of the phosphorus oxychloride was distilled off, and the residue was poured into water. The precipitate of oxadiazole which formed after neutralization with concentrated ammonia was filtered off, washed with water, and dried. After recrystallization from dioxane and chromatographic purification, m.p. 211-212°. Yield 2.5 g (27%).

Found %: N 21.02. $C_{13}H_8O_3N_4$. Calculated %: N 21.22.

Synthesis of 2-(α-Naphthyl)-5-(α-pyridyl)-1,3,4-oxadiazole

1-(α-Naphthoyl)-2-(α-pyridoyl)hydrazine. To a mixture of 13.3 g of the hydrazide of α-pyridinecarboxylic (picolinic) acid [8] and 140 ml of dry pyridine was added 18.7 g of α-naphthoic acid chloride. After two hours the reaction mass was treated with 0.6 liters of water, the precipitate of 1-(α-naphthoyl)-2-(α-pyridoyl)-hydrazine was filtered off, washed with water, and dried. After recrystallization from dioxane and chromatographic purification, m.p. 148.5-149°. Yield 16.3 g (58%).

Found %: N 14.61. $C_{17}H_{13}O_2N_3$. Calculated %: N 14.43.

2-(α-Naphthyl)-5-(α-pyridyl)-1,3,4-oxadiazole. A mixture of 20.7 g of 1-(α-naphthoyl)hydrazine and 100 ml of phosphorus oxychloride was boiled to full solution of the precipitate, which took about four hours. Then the reaction mass was poured into 0.5 liter of water and the resulting oxadiazole was recrystallized from alcohol with addition of diethylamine, twice from benzene, and finally, was submitted to chromatographic purification on aluminum oxide. M.p. 149.5-150°. Yield 3 g (16%).

Found %: N 15.48. $C_{17}H_{11}ON_3$. Calculated %: N 15.38.

SUMMARY

We have synthesized the unreported 2-(p-tolyl)-5-(β-pyridyl)- ,2-p-methoxyphenyl)-5-(β-pyridyl)-2-(p-chlorophenyl)-5-(β-pyridyl)- , 2-(p-nitrophenyl)-5-(β-pyridyl)-, and 2-(α-naphthyl)-5-(α-pyridyl)-1,3,4-oxadiazoles, and also the corresponding hydrazides from which they were obtained.

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STUDIES IN THE FURAN SERIES

XV. STEREOCHEMISTRY OF ADDITION TO THE C = C BOND

IN THE 3,6-ENDOXOCYCLOHEXENE SERIES

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In the work of a number of investigators [1-9] it was established that addition of different reagents to the C = C bond in the bicyclic system of endomethylenecyclohexene and to the exocyclic bonds C = C, C = O, C = N in the endomethylenecyclohexene system occurs to a considerable degree stereospecifically and is exo-addition. We should note that the literature indications of the stereochemistry of addition to the C = C bond in the endoxocyclohexene system are incomplete and contradictory. Thus, in the synthesis of cantharidine [10] the addition of butadiene to the dimethyl ester of 3,6-endoxo-Δ^1-tetrahydrophthalic acid is exo-addition. Berson and Swidler [11] showed that in bromination of the adduct of furan with maleic anhydride in nonpolar solvents, addition of bromine is exo-cis addition in distinction from the usually found trans-addition. Exo-addition of the bromine cation is also the first step in bromination of the adduct of furan with maleic anhydride in a water medium [12].

In a previous communication [13] we described the epoxylation of the anhydride of 3,6-endoxo-exo-cis-Δ^4-tetrahydrophthalic acid and some reactions of the resulting oxide. In the present work as an example of this epoxylation reaction we have studied the stereochemistry of the addition at the C = C bond in the 3,6-endoxocyclohexene system. For this purpose, in the action of hydrogen bromide in acetic acid on 4,5-epoxy-3,6-endoxo-exo-cis-hexahydrophthalic acid (I) [13], we have obtained the bromohydrin acid (II), in which the hydroxyl occupies the same position as the starting α-oxy ring, while addition of bromine evidently occurs as usual, with a Walden inversion [14, 15].

In establishing the structure of the bromohydrin acid (II) we could not fail to consider that in the action of hydrogen bromide on the oxide (I) there was a possibility of a Wagner-Meerwein rearrangement [16], the more so in that in this series occurred one case of such a rearrangement [12]. However, then compound (IIa) would be formed, that is, α-halogen substituted ether. However, neither the bromohydrin acid nor the dimethyl ester (III) obtained from it by the action of an alcoholic solution of silver nitrate gave a precipitate of silver bromide. It is known that α-halogen substituted ethers give a positive result in this test [17] while, for example, the dimethyl ester of trans-4,5-dibromo-3,6-endoxohexahydrophthalic acid is unusually stable to solvolysis and does not give a precipitate of silver bromide when silver salts in various solvents act on it [18]. Hence it follows that when hydrogen bromide acts on oxide (I), a rearrangement does not occur. Also, the bromohydrin acid (II) is thermally stable and stable in an alkaline medium, while from compound (IIa) we could expect easy splitting of hydrogen bromide under conditions which occur, for example, in alkaline hydrolysis of the anhydride of 4,7-dibromo-3,6-endomethylenehexahydrophthalic acid [19].

On treatment with skeletal nickel, and also by hydrogenation in an alkaline medium in the presence of palladium we converted the bromohydrin acid (II) into the corresponding hydroxydicarboxylic acid (IV) from which by the action of diazomethane we obtained the dimethyl ester of the hydroxydicarboxylic acid (V).

Under the action of acetyl chloride on the hydroxydiester (V) we obtained its acetate (VI) and by oxidation with chromic anhydride we obtained the corresponding dimethyl ester of the ketodicarboxylic acid (VII), isolated as its 2,4-dinitrophenylhydrazone.

We also carried out the direct synthesis of the hydroxydiester (V) from the dimethyl ester of oxide (VIII) by catalytic hydrogenation of the latter in methyl alcohol with an initial pressure of 100 atm and 120° in the presence of skeletal nickel.

(I) → (II) Br → (III) Br

(IIa) ≡
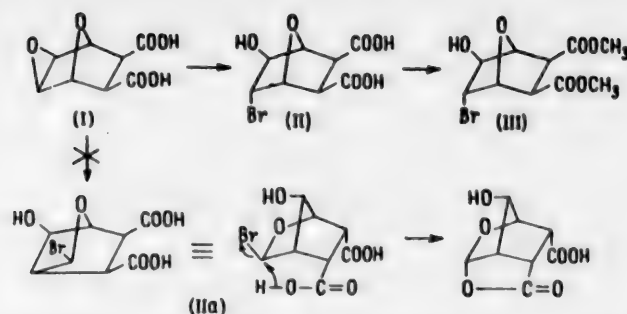
As is known, the hydrogenation of α-oxides occurs with maintainance of configuration on that carbon atom on which the oxygen of the oxide ring remains [6]. The preparations of hydroxydiester (V) obtained in the two ways were identical. All this confirmed that the hydroxyl in the hydroxydiester (V) occupies the same position as the epoxide ring in the oxide (I).

(II)

(VIII)

(IV) → (V)

(VI)   (VII)
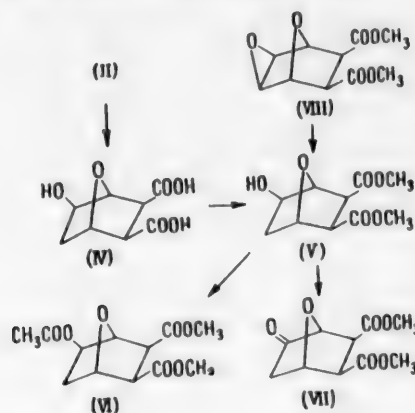
In order to reach a final settlement of the question of whether the hydroxyl in the hydroxydiester (V) is in the exo-or the endo-position we studied its alkaline hydrolysis.

As was known from many examples in the endoxo and endomethylenecyclohexane series, alkaline hydrolysis of esters of cis-dicarboxylic acids occurs with inversion of configuration and leads to the corresponding trans-acids [19-21]. In the case of the exo-configuration of the hydroxyl in the hydroxydiester (V) its alkaline hydrolysis should lead to a mixture of hydroxy-trans-acid (IX) from which the action of diazomethane should give a mixture of diesters, and when the latter is acetylated, a mixture of acetates (XI):

(V) → R'O—⟨ ⟩—COOR ··· COOR   +   R'O—⟨ ⟩—COOR ··· COOR

(X) R=R'=H ; (X) R=CH₃, R'=H ; (XI) R=CH₃, R'=CH₃CO .
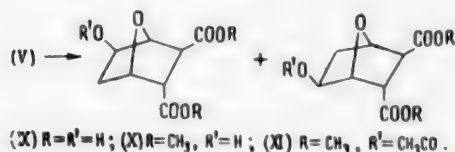
In the case of the endo-configuration alkaline hydrolysis should give lactone (XII) and then its monomethyl ester (XIII) by the scheme:

COOCH₃ COOCH₃ OH → COOR O—C=O   (XII) R=H , (XIII) R=CH₃ .
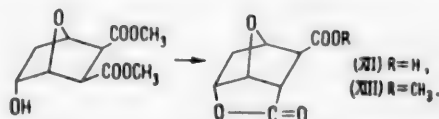
We obtained a mixture of hydroxydiesters (X) and thus established that alkaline hydrolysis of (V) occurs according to the first possible scheme. When this mixture of hydroxydiesters (X) was acetylated we obtained a mixture of crystalline and oily acetates (XI) from which the first was isolated in pure form (XIa). It should be noted that in

one of the experiments on hydrogenation of dimethyl ester of oxide (VIII), which was carried out in methanol in the presence of skeletal nickel at initial pressure of 100 atm and 160°, we obtained not the expected hydroxydiester (V), but its isomeric substance (Xa). This compound gave an acetate which from the infrared spectrum and absence of depression of mixed melting points was identical with acetate (XIa) obtained in the alkaline hydrolysis of (V). Thus, hydrogenation at such a high temperature was accompanied by isomerization of the carbomethoxy group from the cis- to the trans-position and this process occurred more simply than alkaline hydrolysis and led to one of the possible trans-diesters (X) or, in the case taken, to a considerable predominance of one of them.

Getting the trans-diester (X) in the hydrolysis shows that the hydroxyl in the hydroxydiester (V) and hence the epoxy ring in oxide (I) occupy the exo-position, and addition to the C = C bond in the system of endoxocyclohexene is an exo-addition.

In conclusion it is necessary to bring up the question of the configuration of the adduct from furan, 2-methyl-furan, and 2,5-dimethylfuran and maleic anhydride (XIVa, b, c) and their hydrogenated derivatives. In the work of Alder and co-workers [22, 23] adducts (XIVb) and (XIVc) on the basis of results of their bromination in water solution, and adduct (XIVa) on the basis of bromination of the adduct of furan with maleic acid were ascribed the endo-configuration. Evidently in this case their hydrogenated derivatives should also have the endo-configuration. However, on hydrogenation of the adducts of furan, 2-methylfuran, and 2,5-dimethylfuran with acetylene dicarboxylic acid (XVa, b, c) there were obtained the corresponding cis-acids and their anhydrides, not identical with those obtained from adducts (XIV) [9]. On this basis it was erroneously concluded that in the hydrogenation of adducts (XV) the exo-derivatives (XVI) were obtained, and thus addition to the system of 3,6-endoxocyclohexene was endo-addition [9]. However, Woodward and Baer [12] showed that adduct (XIVa) had the exo-configuration, and so in the case of the hydrogenation of adduct (XVa) there was obtained (XVII a) with the endo-configuration [and not (XVIa) the exo-con-figuration].

Since from a consideration of the literature material and the results of our present work it follows that addition at the C = C bond with the system of 3,6-endoxocyclohexene is exo-addition, we should conclude that in the case of hydrogenation of adducts (XVb) and (XVc) there are obtained the corresponding derivatives (XVIIb) and (XVIIc) of

a) R=R'=H ; b) R=H; R'=CH₃ ; c) R=R'=CH₃.
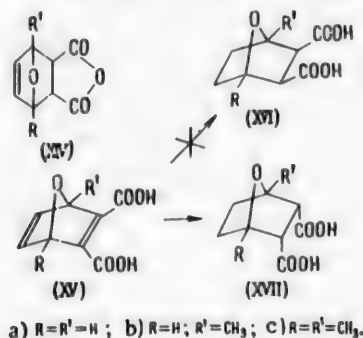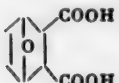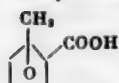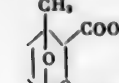
the endo-series and hence adducts (XIVb) and (XIVc) should have the exo-configuration. This is in agreement with the fact that after establishing the true configuration of the hydrogenated adducts of furan and its methyl homologs with maleic anhydride, and also the dicarboxylic acids obtained from them, we find the same regularities in the melt-ing points of the anhydrides obtained from furan and 2,5-dimethylfuran as in the series of endomethylenecyclohexane: The exo-form melts below the correspomding endo-form, as the table shows.

Thus we show the error of the Alder opinion [9], that in the melting points of the exo- and endo-forms of these furan and 2,5-dimethylfuran derivatives there are opposite regularities to those in the endomethylenecyclohexane series. This also shows the need for correcting the literature data on bromination of the adducts (XIVb) and (XIVc) in aqueous media [23].

EXPERIMENTAL

5-Bromo-4-exo-hydroxy-3,6-endoxo-cis-hexahydrophthalic acid (II). In a flask with a stirrer, thermometer, reflux condenser, and gas ingress tube was suspended 40 g of oxide (I) in 400 ml of glacial acetic acid and a stream of gaseous hydrogen bromide was passed in, in such a way that the temperature was kept at 20-25°. During the reac-tion the substance dissolved and the solution darkened; when it became homogeneous (≈ 6 hr) the acetic acid was

Substance	Melting point	
	exo-form	endo-form
(structure) COOH / O / COOH	122—123°	169—170°
Anhydride	116—117	158—159
(structure) CH₃ / COOH / O / COOH	158	160—161
Anhydride	105—106	87—89
(structure) CH₃ / COOH / O / COOH / CH₃	—	202—203
Anhydride	122—123	175—177

distilled off in a vacuum at not above 25°. The dark oil which remained crystallized slowly (even when a primer was added). The solid substance was ground with methyl acetate and filtered; this operation was repeated and the precipitate on the filter should become gray (and not black). It was dissolved in water, treated with activated charcoal at 60°, filtered and the colorless or pale yellow solution was evaporated in a vacuum almost to dryness. The precipitate was filtered off, ground with methyl acetate, and filtered. We obtained 35 g (62%) of the bromohydrin acid (II) as a white powder, soluble in water, methanol, less so in acetic acid, and insoluble in methyl acetate, and acetonitrile; m.p. 168-168.5° (after solution in a small amount of water treatment with charcoal, filtration, and partial evaporation on a watch glass); the solution of (II) did not form a precipitate of silver bromide when mixed with an alcoholic solution of silver nitrate.

Found %: C 34.22, 34.36; H 3.36, 3.29. $C_8H_9O_6Br$. Calculated %: C 34.18; H 3.23.

For later transformation into the hydroxydicarboxylic acid (IV) we could use the oily bromohydrin acid also.

Dimethyl ester of 5-bromo-4-exo-hydroxy-3,6-endoxo-exo-cis-hexahydrophthalic acid (III). Two g of (II) with 20 ml of methanol and several drops of oleum was boiled for five hours, mixed with barium carbonate to a neutral reaction, centrifuged, and the solution evaporated dry. We obtained 1.9 g of (III) in the form of white needles; m.p. 105-105.5° (from water).

Found %: C 38.97, 39.14; H 4.39, 4.38. $C_{10}H_{13}O_6Br$. Calculated %: C 38.85; H 4.24.

A solution of (III) did not form a precipitate when added to an alcoholic solution of silver nitrate.

4-Exo-hydroxy-3,6-endoxo-exo-cis-hexahydrophthalic acid (IV). a) Five g of (II) was boiled for five hours in 150 ml of water with 50 g of Raney nickel and several drops of decyl alcohol, filtered, and the precipitate carefully washed with water on the filter. The filtrate and wash water were evaporated in a vacuum to 50 ml, treated with ion exchange resin KU-2 in the H^+ form, with charcoal at 60°, evaporated in a vacuum almost to dryness and the hydroxyacid (IV) was separated, ground with methyl acetate, and filtered. We obtained 1.3 g (33%) of (IV) in the form of a white powder, soluble in water and methanol, insoluble in acetic acid, acetonitrile, and methyl acetate; m.p. 161-162° [after purification like (II)].

Found %: C 47.37, 47.51; H 5.14, 5.16. $C_8H_{10}O_6$. Calculated %: C 47.52; H 4.99.

A sample mixed with (II) melted at 152-158°; (II) and (IV) were easily separated on a paper chromatogram in the system butanol-water.

b) Ten g of (II) in 100 ml of water was mixed at 5° with a solution of 6.5 g of potassium hydroxide in 30 ml of water and hydrogenated at ordinary pressure and temperature in the presence of 1 g of palladium sulfate (5% Pd). The catalyst was separated, the filtrate was treated with KU-2 resin in the H$^+$ form, and then as described above. We obtained 4.2 g (54%) of (IV).

Dimethyl ester of 4-exo-hydroxy-3,6-endoxo-exo-cis-hexahydrophthalic acid (V). a) We methylated 1.7 g of (IV) with an ether solution of 2 g of diazomethane. We obtained 1.6 g of (V), m.p. 99-100° (from methyl acetate).

Found %: C 52.23, 52.40; H 6.24, 6.37. C$_{10}$H$_{14}$O$_6$. Calculated %: C 52.17; H 6.13.

b) We suspended 11.4 g of the dimethyl ester of oxide (VIII) in 125 ml of methanol and hydrogenated at 100 atm initial hydrogen pressure and 120° in the presence of Raney nickel. By further treatment we obtained 8.5 g (74%) of (V); m.p. 99-100°. A sample mixed with the previous preparation gave no melting point depression.

Dimethyl ester of 4-exo-acetoxy-3,6-endoxo-exo-cis-hexahydrophthalic acid (VI). We boiled 0.1 g of (V) for one hour with 1 ml of acetyl chloride and evaporated dry in a vacuum. We obtained 70 mg of (VI); m.p. 105° (from water with charcoal).

Found %: C 53.15, 53.13; H 6.13; 6.29. C$_{12}$H$_{16}$O$_7$. Calculated %: C 52.93; H 5.92.

A sample mixed with (V) melted at 80-82°.

Dimethyl ester of 4-keto-3,6-endoxo-exo-cis-hexahydrophthalic acid (VII). We dissolved 0.7 g of (V) in 10 ml of glacial acetic acid and added 0.3 g of chromic anhydride in portions with stirring, keeping the temperature at about 40° and stirring the mixture for eight hours. Then we evaporated dry in a vacuum, extracted the residue with benzene, and after distillation of the benzene obtained the ketoester (VII) in the form of viscous oil from which, by the usual treatment, we obtained the 2,4-dinitrophenylhydrazone; m.p. 228-229.5° (with decomposition; from acetonitrile); yellow platelets.

Found %: C 47.03, 46.84; H 3.97, 4.13. C$_{16}$H$_{16}$O$_9$N$_4$. Calculated %: C 47.06; H 3.95.

Alkaline hydrolysis of (V). One g of (V) was boiled for three hours with a solution of 1 g of potassium hydroxide in 20 ml of methanol, 5 ml of water was added, and it was again boiled for three hours. Then the mixture was evaporated in a vacuum, the residue was dissolved in a small amount of water, treated with ion exchange resin KU-2 in the H$^+$ form, and evaporated in a vacuum. We obtained a mixture of the hydroxy-trans acid (IX) as a viscous oil which was dissolved in a small amount of methanol, 1.4 g of diazomethane was added in ether solution, the mixture was left overnight, and then evaporated dry. We obtained a mixture of trans-diesters which was purified by one complete reprecipitation from methyl acetate by ether, so as to avoid the possibility of fractional crystallization of isomeric trans-diesters, and also the possible loss of admixed lactone (XIII). We obtained 0.86 g of a mixture of trans-diesters (X) with m.p. 72-76°.

Found %: C 51.98, 51.83; H 6.16, 6.17. C$_{10}$H$_{14}$O$_6$. Calculated %: C 52.17; H 6.13.

For the methyl ester of lactone (XIII), calculated %: C 54.53; H 5.08.

Seventy mg of the mixture of trans-diester (X) was boiled for one hour with 1 ml of acetyl chloride, evaporated dry in a vacuum, and the crystals were pressed free of oil on a porous plate. We obtained 33 mg of dimethyl ester of 4-exo-acetoxy-3,6-endoxo-trans-hexahydrophthalic acid (XIa); m.p. 101° (from water).

Found %: C 52.76; 52.84; H 5.92, 5.97. C$_{12}$H$_{16}$O$_7$. Calculated %: C 52.93; H 5.92.

Infrared spectrum:[*] 722 (w), 778 (s), 792 (w), 804 (w), 816 (s), 822 (m), 860 (w), 808 (s), 884 (s), 912 (s), 920 (m), 930 (s), 976 (s), 986 (s), 1010 (s), 1034 (m), 1068 (s), 1098 (w), 1170 (w), 1190 (s), 1212 (s), 1234 (w), 1240 (w), 1254 (m), 1292 (s), 1302 (s), 1332 (m), 1376 (s), 1460 (s), 1730 (s).

A sample mixed with (VI) melted at 79-80°.

In one of the experiments, 3.8 g of dimethyl ester of exo-4,5-epoxy-3,6-endoxo-exo-cis-hexahydrophthalic acid (VIII) was hydrogenated at 160° and initial pressure 100 atm as described above in obtaining (V). We obtained 2.9 g of the dimethyl ester of 4-exo-hydroxy-3,6-endoxo-trans-hexahydrophthalic acid (Xa); m.p. 91° (from methyl acetate).

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[*] (s) strong; (m) medium; (w) weak. We express thanks to L. A. Kazitsina for the infrared spectra.

Found %: C 51.91, 51.74; H 5.95, 6.04. $C_{10}H_{10}O_5$. Calculated %: C 52.17; H 6.13.

A sample mixed with (V) melted at 72-74°; mixed with (X), at 86-87°.

We boiled 0.1 g of (Xa) with 1 ml of acetyl chloride for one hour and evaporated dry in a vacuum. We obtained 95 mg of (XIa) as shown by the absence of depression of the melting point mixed with (XIa) and the identity of the infrared spectrum with the spectrum of the preparation of (XIa) obtained by alkaline hydrolysis.

SUMMARY

Addition to the C = C bond in the system 3,6-endoxocyclohexene studied by the reaction of the α-oxide obtained by epoxidation of exo-3,6-endoxo- Δ^4-tetrahydrophthalic anhydride is exo-addition.

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THE MOLECULAR STRUCTURE OF THE PRODUCT
OF LOW TEMPERATURE DEAMINATION OF MELAMINE

A. I. Finkel'shtein

Heating melamine at atmospheric pressure to 320° causes deamination with formation of a product which is practically insoluble in water and poorly soluble in acids and alkalis. It was shown earlier [1] that this product can be contained in recrystallized melamine.

Up to the present it has been considered [2, 3] that the low temperature deamination product is formed by splitting out one molecule of ammonia from two molecules of melamine. This substance was called melam by Liebig [4]. The structural formula of melam (I) was assigned by Klasson [5] and accepted by later investigators [6].
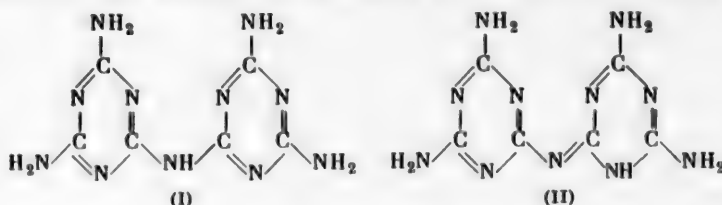
Studies of the ultraviolet spectra [1] showed that formula (I) does not explain the sharp spectral difference of the deamination product from the spectrum of melamine. Therefore formula (I) was modified into formula (II).

However, investigation of the infrared spectrum of the deamination product [7] did not agree with formula (II) in view of the absence of absorption bands with a frequency of 1560 cm^{-1} characteristic for S-triazine derivatives with a benzenoid structure of the ring [8]. Instead of these bands we found three absorption bands: 1615, 1435, and 795 cm^{-1}, characteristic for derivatives of cyameluric acid. The result led to the conclusion that the low temperature product of deamination of melamine was melem, the triamide of cyameluric acid.

In the present paper we give the results of chemical experiments which confirm this conclusion.

EXPERIMENTAL

Investigation of the deamination process was carried out in an apparatus which consisted of a test tube stoppered with a stopper bearing two tubes. One of these was designed for carrying the ammonia which formed to a flask for titration, the other for flushing out the ammonia at the end of the experiment. A sample of melamine was placed in the test tube which was stoppered and placed in a thermostat. The ammonia which formed was titrated with 0.1 N HCl with phenolphthalein. At the end of the experiment the ammonia which remained in the flask was blown out into the titration flask and the reaction product was removed from the test tube and ground. Unreacted melamine was determined by the cyanurate method [9].

The deamination of melamine at atmospheric pressure begins at 320°. After a short induction period there is an even evolution of ammonia which lasts from 10 min at 420° to almost 2 hr at 325°. After this, the process slows, although all the melamine is still not decomposed.

*G. V. Zavarov (personal communication) in 1957 studied the deamination of melamine at 350° and showed that the resulting product could not be melam, since if we consider not only the amount of ammonia evolved, but also the quantity of melamine in the residue, we will obtain a molar ratio of amount of reacting melamine to the amount of ammonia equal to 1 and not 2, which corresponds to melem formation. The author has used the method of V. G. Zavarov for the study of melamine deamination at different temperatures.

As Table 1 shows, the ratio of the number of moles of ammonia, M_{NH_3}, to the number of moles of melamine reacting, M_{mel}, in all the experiments was close to unity, which corresponds to the formation of melem and not melam, since in the latter case the ratio $M_{NH_3} : M_{mel}$ should be close to 0.5.* We note the regular decrease in content of

TABLE 1

Expt. No.	Tempera- ture	Duration of expt min	Melamine content in product, wt.%	$\dfrac{M_{NH_3}}{M_{mel}}$
1	$325 \pm 1.5°$	95	74.2	0.93
2	325 ± 5	110	66.3	1.03
3	350 ± 10	35	48.5	0.97
4	360 ± 10	40	44.5	0.99
5	365 ± 5	28	49.2	1.06
6	390 ± 10	25	36.9	0.99
7*	435 ± 5	10	53.9	1.02
8**	320—420	—	25.3	1.04

* Violent reaction with ejection of melamine into the upper part of the tube.
** Continuous increase in temperature.

unreacted melamine in the reaction product. Only Expt. 7 at 435° is an exception, where there is a stormy course of the experiment which leads to ejection of some of the melamine into the upper part of the tube, which is not heated. To prevent this, we ran an experiment with a constantly rising temperature. Here ejection did not occur, and the content of melamine corresponded to that expected at the given temperature (Expt. 8).

Study of the infrared spectrum of the water insoluble product formed by heating cyanamide to 120° and dicyandiamide to 190° showed that these products were also melem.

We can explain the observed effect, starting from the assumption that the deamination process can occur with marked speed only in the liquid phase. Therefore the process begins at a temperature somewhat below the melting point of melamine (354°), since small admixtures of the reaction product lower the melting point of the mixture. With increasing content of melem the melting point of the mixture passes through a minimum close to 320° and rises, the mixture solidifies, and the deamination process is hindered. At higher temperatures solidification of the mixture of melamine and melem occurs at greater melem content and so under these conditions more complete deamination occurs. In the presence of easily melting substances (for example, dicyandiamide) the melting point of the mixture is lowered and formation of melem begins at a lower temperature.

In Table 2 we give the results of elementary analyses of the product of deamination with calculations of the amount of nitrogen, carbon, and hydrogen in the molecules of melem and melam. As Table 2 shows, the results of analysis of the product of deamination are closer to the values calculated for melem.

For confirmation of these conclusions of the direct formation of melem in the deamination of melamine we carried out three independent experiments.

TABLE 2

	Content, %		
	C	N	H
Deamination product of melamine (determined)	33.0	63.7	3.36
Melem (calculated for $C_6N_{10}H_6$)	33.0	64.3	2.75
Melam (calculated for $C_6N_{11}H_9$)	30.67	65.5	3.83

1. A sample of 0.2 g of deamination product and 200 ml of 30% nitric acid were placed in a flask with a reflux condenser and kept on a boiling water bath for 20 hours; the sample was not changed. The infrared spectrum of the substance after treatment and that of the untreated product were identical, which shows the stability of the deamination product to treatment with nitric acid at 100°. Under these conditions, all amino derivatives of S-triazines are converted into cyanuric acid, which is dissolved. This experiment shows that the deamination product of melamine is not a derivative of S-triazine.

2. Hydrolysis of an alkaline solution of the deamination product gives potassium cyamelurate, whose infrared and ultraviolet spectra are identical with the spectra of potassium cyamelurate obtained from melon.

3. Fusing the deamination product with ammonium thiocyanate gives, like melon, potassium hydromelonate. The identity of the reaction products was established by infrared and ultraviolet spectra. Experiment 3, like experiment 2, confirmed the reality of the relation of the deamination product to derivatives of cyameluric acid.

Thus, the combination of all these experiments uniformly shows that the low temperature deamination product of melamine is a derivative of cyameluric acid which can only be melem, the triamide of cyameluric acid. The structural formula of melem (III) is given according to the results of [10]. The structural formula of melem (IV) is written with use of the system of supplementary conventional signs [11].
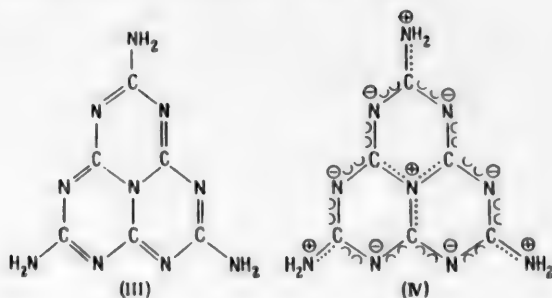
SUMMARY

1. It is shown that on thermal decomposition of melamine at atmospheric pressure and 320-435° one molecule of ammonia is evolved per molecule of reacting melamine.

2. The earlier spectroscopic study and the chemical investigation carried out in the present work show that the first product of thermal decomposition of melamine is melem, the triamide of cyameluric acid.

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STUDIES IN THE FIELD OF CONJUGATED SYSTEMS

CXXXIII. THE ADDITION OF LITHIUM DIALKYLAMIDES

TO TRIALKYLSILYL-3-BUTENYNE*

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It was shown previously that lithium dialkylamides can add easily to vinylacetylene hydrocarbons with the formation, depending on the structure of the latter, of acetylene or allene amines [1]. Vinylmethylacetylene added lithium diethylamide and lithium piperidide with formation of acetylene amines, and lithium dibutylamide with formation of allene amines or mixtures of allene and acetylene amines. Vinylethylacetylene and higher homologs under the same conditions gave only allene amines.

The strong dependence of the direction of the reaction on structural factors made especially interesting the further study of the field of reaction of lithium dialkylamides with enyne compounds.

In the present communication we describe the reactions of lithium diethylamide and lithium piperidine with the simplest representative of the silicoorganic vinylacetylenes, 1-trimethylsilyl-3- buten-1-yne.

1-Trimethylsilyl-3-buten-1-yne, like the vinylacetylene hydrocarbons, adds lithium dialkylamides even in the cold. However, due to the slight stability to hydrolysis of the carbon-silicon bond in the α-position to the multiple bond, treatment of the adduct with water too a greater or lesser degree causes splitting of the original adduct with formation of an amine and hexamethylsiloxane.

In the reaction of 1-trimethylsilyl-3-buten-1-yne with lithium diethylamide we obtained a mixture of similar amounts of acetylene (I) and allene (II) silicon-containing amines.

$$(CH_3)_3Si-C\equiv C-CH=CH_2-\begin{cases} \rightarrow (CH_3)_3Si-C\equiv C-CH_2-CH_2N(C_2H_5)_2 \quad (I) \\ \\ \rightarrow (CH_3)_3Si-CH=C=CH-CH_2N(C_2H_5)_2 \quad (II) \end{cases}$$

In the infrared spectra of this mixture there was a very intense frequency of valence oscillation of the acetylene bond (2171 cm^{-1}), which was considerably lower compared to the frequency of the acetylene bond in other disubstituted acetylene compounds. There was also an intense band of valence oscillation of the allene group (1937 cm^{-1}), also somewhat less than its usual value. In the region 1600 cm^{-1} the substance notably had no absorption.. Hence the isomer with a conjugated system of double bonds was absent from the reaction product. This fact is also confirmed by the absence of absorption in the region of deformation oscillation at $900-1000 \text{ cm}^{-1}$. The characteristic frequencies at 1208 and 1256 cm^{-1} are connected with the presence of a silicon atom in the compound, and the frequencies 843 and 762 cm^{-1} are connected with the presence of the $(CH_3)_3Si$ group [2]. We note the very high intensity of the band at 843 cm^{-1}.

On heating with a 10% KOH solution in methanol there is very strong hydrolysis of the mixture with formation of hexamethylsiloxane and a mixture of acetylene and allene amines.

In the infrared spectrum of this mixture the ratio of intensities of valence oscillation frequencies of acetylene and allene bonds is opposite to the starting compounds. Hence, either by heating with alkali or by other treatment

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*Enyne Compound. LII.
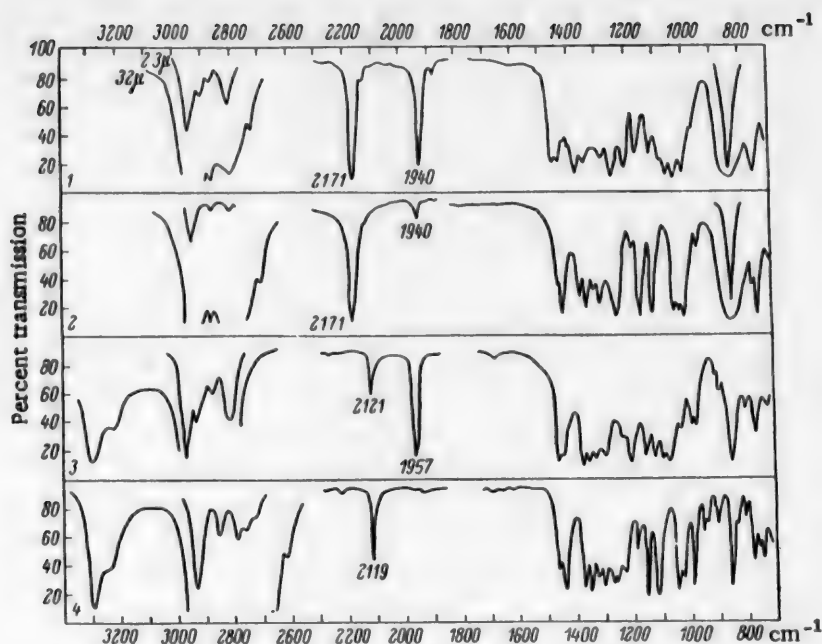
Infrared transmission spectra. 1) Adduct of lithium diethylamide to 1-tri-methylsilyl-3-buten-1-yne; 2) adduct of lithium piperidide to 1-trimethyl-silyl-3-buten-1-yne; 3) mixture of 1-diethylamino-3-butyne and 1-diethyl-amino-2,3-butadiene; 4) 1-piperidino-3-butyne mixed with 1-piperidino-2,3-butadiene.

connected with the isolation of the amines in pure form there is isomerization with change in the character of the multiple bonds, or in the spectrum of the starting compound the intensity of the band of valence oscillation of the triple bond is strongly increased by its nearness to the silicon atom. The latter assumption seems more probable to us.

The mixture of amines boils close to the boiling point of the pure acetylene amine which is described in the literature [5]. However, by the usual analytical determination we found in it 35%, in all, of the acetylene amines. On hydrogenation over colloidal palladium the substance absorbed the required amount of hydrogen and gave diethyl-butylamine, which was identified by the constants and infrared spectrum.

Thus, no doubt remains of the reality of the mixture of amines as structural components.

In the reaction of trimethylsilylbutenyne with lithium piperidide we obtained a mixture of amines free from silicon, and a mixture of amines which contained silicon.

The first product was almost pure 1-piperidino-3-butyne, described in the literature [3] and previously obtained by us by the action of lithium piperidine on vinylacetylene [1]. Analytical determination showed that it contained 90% of the compound with the terminal acetylene group. The infrared spectrum of the substance almost completely agreed with the spectrum of 1-piperidino-3-butyne. There was a small difference only in the region of 2220 cm^{-1} (evidently there is a weak frequency of disubstituted acetylene at 2223 cm^{-1}) and the frequency 863 cm^{-1} had greater intensity (because of a small admixture of allene).

The second product is an adduct of piperidine and trimethylsilyl-3-buten-1-yne, and its structure is also almost entirely that of an acetylene compound.

In the infrared spectrum of the substance there is an intense band of valence oscillation of the triple bond at the same place in the spectrum as in the adduct with diethylamine (2171 cm^{-1}). The band of valence oscillation of the allene group is weak. The other frequencies due to the presence of the $(CH_3)_3Si$ group had the same values relatively as for the diethylamine adduct.

Thus it was shown that in distinction from vinylalkylacetylenes, 1-trimethylsilyl-3-buten-1-yne has a tendency to form acetylene compounds in the reaction with lithium dialkylamides. This can be interpreted as showing the great

tendency of the substance to 1,2-addition: The silicon atom lessens the reactivity of the acetylene carbon atom bound to it in respect to lithium. It is possible that this effect depends on the conjugation of the free electrons of the triple bond with the silicon atom because of its unfilled d-shell.

We also note the dependence of order of addition on the nature (basicity ?) of the amine. In the vinylacetylene series this was not the case.

The formation in the reaction with lithium piperidide of products which do not contain silicon is chiefly the result of the instability toward bases of the carbon-silicon bond,and cannot be explained as the result of conjugated bonding with the $(CH_3)_3Si$ radical which is removed.

Some comments can be made on the other properties of the adducts, though they are mixtures.

Both silicon-containing amines are colorless oils which turn somewhat yellow on long keeping with access of air; they dissolve completely in dilute hydrochloric acid, but when reprecipitated they are partly split at the carbon-silicon bond.

When hydrogenated over $Pd/CaCO_3$, the mixture of amines (I) and (II) smoothly add the required amount of hydrogen and give the corresponding saturated amines.

EXPERIMENTAL

Reaction of trimethylsilylbutenyne with lithium diethylamide. To an ether solution of lithium diethylamide cooled to 15° and prepared from 6 g of lithium was added 10 g of trimethylsilylbutenyne. The reaction mixture took on a brick red color. After one hour the mixture was treated with water and the resulting oil was distilled. The ether and a large part of the diethylamine were distilled off at ordinary pressure, the residue was distilled in a vacuum. We thus obtained about 10 g (62%) of a mixture of allene and acetylene amines and about 1.2 g of residue.

The mixture of 4-diethylamino-1-butynyl trimethylsilane and 4-diethylamino-1,2-butadienyl trimethylsilane had the constants:

B.p. 102.5-103.5° (20 mm), d^{20}_4 0.8126, $n^{20}D$ 1.4522, MR 65.54. $C_{11}H_{23}SiNF_2$. Calculated: 65.56.

Found %: N 6.90, 7.15. $C_{11}H_{23}SiN$. Calculated %: N 7.10.

Infrared spectrum: 762 (s), 843 v.s., 974 w, 1013 s, 1036 s, 1041 s, 1090 m, 1122 s, 1165 s, 1208 s, 1256 v.s., 1350 s, 1381 v.s., 1408 w, 1427 w, 1454 s, 1888 w, 1940 s, 2133 w, 2175 v.s., 2808 v.s., 2875 s, 2900 s, 2964 v.s. cm^{-1}.

On hydrogenation of 3.18 g of substance in 40 ml of methanol over 1.9 g of $Pd/CaCO_3$, 840 ml of H_2 were absorbed (761.5 mm, 21°) which corresponds to 106.5% of the theory. Distillation separated a saturated silicon-containing amine.

B.p. 83-84° (10 mm), d^{20}_4 0.7882, $n^{20}D$ 1.4340. MR 66.54; calc. 66.50.

Found %: Si 14.11, 14.06. $C_{11}H_{27}SiN$. Calculated %: Si 13.93.

On heating 6 g of the amine mixture with 30 ml of 10% KOH in methanol for two hours there occurred full splitting of both amines. The reaction mixture was diluted with water and the resulting product was distilled with water and alcohol. To the distillate was added 5 ml of concentrated hydrochloric acid. The upper, oily layer of hexamethylsiloxane was separated. The lower layer was evaporated in a vacuum to small volume and from it by the action of solid NaOH we isolated a mixture of amines which did not contain silicon.

Hexamethylsiloxane (1.6 g, 65%).

B.p. 99.5-100°, d^{20}_4 0.7618, $n^{20}D$ 1.3778, which agree with the literature data [6].

The mixture of 1-diethylamino-3-butyne and 1-diethylamino-2,3-butadiene (2.5 g, 60%).

B.p. 143-148°, d^{20}_4 0.8029, $n^{20}D$ 1.4450.

Found %: N 12.13, 12.28. $C_8H_{15}N$. Calculated %: N 12.08.

Content of acetylene amine 34.9, 34.4% [4].

Infrared spectrum: 730 m, 768 s, 804 m, 841 v.s., 889 w, 910 w, 996 m, 1033 m, 1067 v.s., 1090 s, 1119 s, 1161 s, 1204 s, 1238 m, 1294 s, 1323 s, 1354 s, 1375 v.s., 1448 s, 1468 s, 1957 v.s., 2121 m, 2809 v.s, 2873 s, 2932 s, 2967 v.s. cm^{-1}.

By exhaustive hydrogenation of the substances we obtained diethylbutylamine with b.p. 136-138° (picrate m.p. 47°).

Reaction of 1-trimethylsilyl-3-buten-1-yne with lithium piperidide. Under the same conditions, from 10 g of 1-trimethylsilyl-3-buten-1-yne and lithium piperidide we obtained 6 g (55%) of a mixture of amines which did not contain silicon, and 3.5 g (21%) of a mixture of silicon-containing amines.

For the first product we found:

B.p. 78-79° (20 mm), d^{20}_4 0.8826, $n^{20}D$ 1.4730.

Found %: N 10.55, 10.30. $C_9H_{19}N$. Calculated %: N 10.21.

Content of acetylene amine 89.36, 89.45%.

Infrared spectrum: 756 m, 767 m, 787 m, 808 s, 843 w, 863 s, 907 w, 920 v.w.,954 w, 965 w, 993 s, 1028 m, 1043 s, 1119 v.s., 1160 s, 1194 w, 1233 m, 1260 m, 1272 m, 1307 s, 1326 m, 1353 s, 1374 s, 1444 s, 1466 s, 1940 w, 2119 s, 2618 w, 2692 s, 2733 s, 2798 s, 2866 s, 2931 v.s. cm^{-1}.

On exhaustive hydrogenation of the substances we obtained N-butylpiperidine with b.p. 175-176°.

For the mixture of amines which contained silicon we found:

B.p. 125-127° (20 mm), d^{20}_4 0.8681, $n^{20}D$ 1.4745, MR 67.85. $C_{12}H_{23}SiNF$. Calculated 67.39.

Found %: N 6.81, 6.60. $C_{12}H_{23}SiN$. Calculated %: N 6.69.

Infrared spectrum: 730 m, 760 s, 788 m, 843 v.s., 964 w, 1016 s, 1030 s, 1042 s, 1117 v.s., 1160 s, 1188 w, 1247 v.s., 1308 s, 1326 m, 1353 s, 1375 m, 1440 s, 1454 s, 1940 w, 2171 v.s, 2693 m, 2797 s, 2866 s, 2930 v.s. cm^{-1}.

When split by alkali the substance gave the mixture of amines described above.

SUMMARY

1. We have studied the reaction of 1-trimethylsilyl-3-buten-1-yne with lithium diethylamide and lithium piperidide.

2. We have shown that as a result of this reaction we obtain a mixture of acetylene and allene amines in different ratios.

3. We have established that the silicon-containing acetylene and allene amines are easily hydrolyzed by the action of alkali with formation of hexamethylsiloxane and a mixture of acetylene and allene amines.

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STUDIES IN THE FIELD OF CONJUGATED SYSTEMS

CXXXIV. CO-"DIMERIZATION" OF DIVINYL WITH DIISOPROPENYL*

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Translated from Zhurnal Obshchei Khimii, Vol. 31, No. 4,
pp. 1140-1143, April, 1961
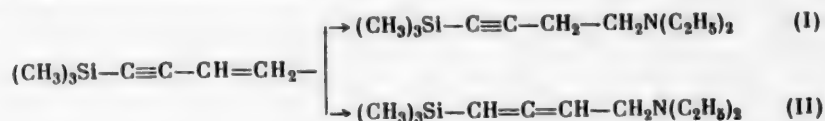Original article submitted April 29, 1960

The ability of diene hydrocarbons to give cyclic dimers when heated was discovered about 85 years ago. The basic rules for this process were established by S. V. Lebedev as long ago as 1913 [1]. In later years the process of dimerization of divinyl, isoprene, and piperylene were again carefully studied, and four and eight membered dimers were discovered along with six membered ones [2, 3].

The "co-dimerization" of different diene hydrocarbons has not been sufficiently studied even ten years after its discovery [4]. Only the work of A. F. Plate and co-workers [5] on "co-dimerization" of divinyl with cyclopentadiene has appeared.

The material accumulated up to now indicates that the direction of the reaction depends on the structure of the diene and the temperature. In the condensation of divinyl with isoprene, piperylene, dipropenyl, and diisopropenyl at 150-155° as the diene components the substituted dienes act preferentially, probably because their molecules are more polarized under the influence of radicals. In the condensation of divinyl with cyclopentadiene the share of participation of each of the hydrocarbons in the reaction as the diene component depends on the temperature.

The structure of the co-"dimer" of divinyl with its homologs was determined by the method of its dehydrogenation to a benzene homolog and the oxidation of the latter with permanganate to the corresponding aromatic acid. Here then occur errors in determining the composition of the starting mixture of hydrocarbons due to incomplete dehydrogenation of the separate components of the mixture and because of the fact that o-, m-, and p-dialkylbenzenes give aromatic acids in different yields. This latter relates especially to the case where one of the isomers is the ortho-isomer. It is known that o-dialkylbenzenes can be oxidized with rupture of the benzene ring.

For a more exact determination of the ratio between the possible co-"dimer," we have again studied the reaction of co-"dimerization" of divinyl with diisopropenyl.

The choice of dienes was based on the following considerations. Because of the symmetric nature of the dienes there is possible here the formation of only two co-"dimers" (I) and (II), which simplifies the analysis of the mixture considerably. The method used previously for showing the structure of the resulting substance in this reaction is very unsuitable, since one of the dimers cannot be dehydrogenated without isomerization. Finally, both possible co-"dimers" were previously obtained by us in pure form by other methods, according to the scheme:

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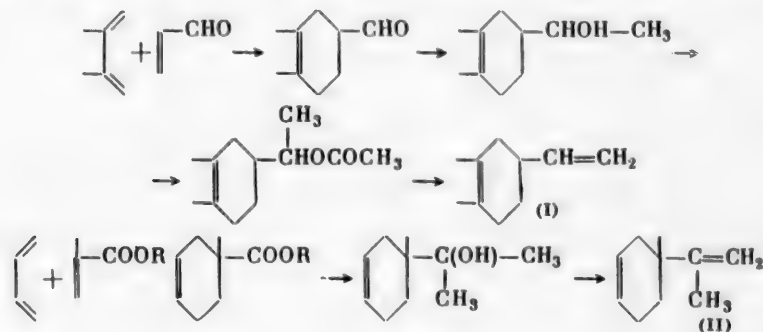
*Diene Compounds. LXXIX.
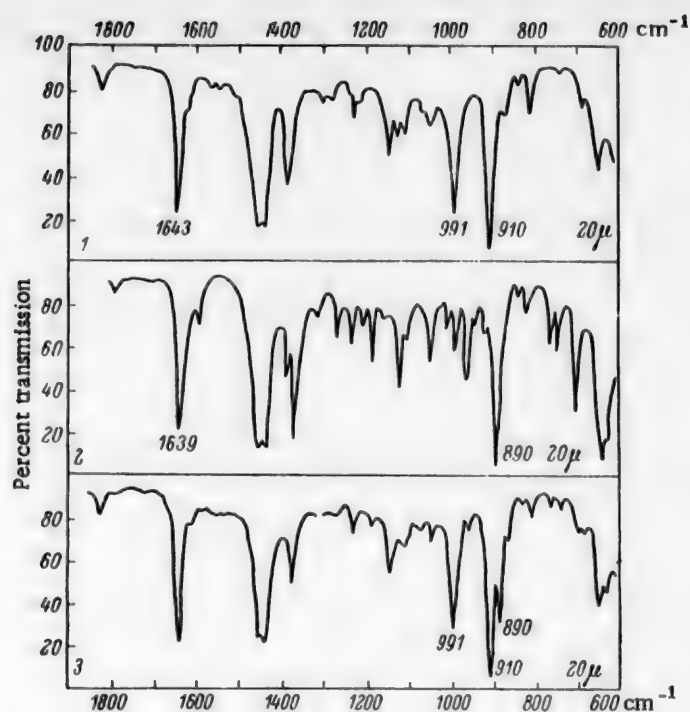
Infrared transmission spectra. 1) 1-Vinyl-3,4-dimethyl-3-cyclo-
hexene; 2) 1-isopropenyl-1-methyl-3-cyclohexene; 3) co-"dimer"
of divinyl with diisopropenyl.

In both cases at all stages of the process there is excluded the formation of any other isomer with a different
arrangement of radicals in the cyclohexene ring.

The ratio between the two isomers in the product of the "dimerization" of divinyl with diisopropenyl was de-
termined by the infrared spectra. In the spectrum of "dimer" (I) (figure, curve 1) there are intense deformation
bands from the divinyl group at 910 and 991 cm^{-1}; in the spectrum of "dimer" (II) (figure, curve 2) there is a very
intense band of the isopropenyl group at 890 cm^{-1}. It was shown that these frequencies permitted determination of
both isomers in the mixture with an accuracy to several percent.

Our reaction was carried out at two temperatures, 120 and 170°. As a result of study of the reaction products
it was established that, independent of the temperature, the process goes with formation of "dimers" (I) and (II) in
the ratio 4 : 1.

The activity of the hydrocarbons depends strongly on temperature: at 120° the ratio between amount of dimer
of divinyl and the mixed "dimer" is about 2 : 1; at 170° it decreases to 1 : 1. The dimer of diisopropylene is formed
in small amounts.

The rate of the reaction also depends strongly on temperature. At 170° the pressure falls from 40 to 5 atm in
two hours. At 120° the fall in pressure from 20 to 5 atm takes 40 hr.

At 120° formation of a rubber-like polymer is scarcely observed; at 170° such a polymer occurs in considerable
amounts. Analysis of the polymer shows that it included in its molecule both hydrocarbons.

The major share in the reaction as the diene component is taken by diisopropylene, which can be explained
by its high polarizability and the greater probability of the "cis-form" in the reactive state.

The reaction goes chiefly through the molecular six membered transitional complex. Formation of the bi-
radical

$$-CH_2-C(CH_3){=}C(CH_3)-CH_2-CH_2-CH{=}CH-CH_2-$$

is unlikely, since hydroquinone is present in the system. To explain the formation of the "dimers" (I) and (II) by
cyclization of such a radical is difficult.

Thus, as a result of this study we have confirmed and made more accurate the conclusions drawn previously on the chief direction of the co-"dimerization" of divinyl with diisopropenyl.

EXPERIMENTAL

The reaction was carried out in a steel rotating autoclave, capacity 0.5 liter. The temperature was maintained with an accuracy of 5°. In the reaction, in both experiments we used 2 g-moles of divinyl, 1 g-mole of diisopropenyl, and 0.5 g of hydroquinone. The dimer was distilled from the polymers with steam. Distillation of the reaction products was carried out in a vacuum on a Widmer column (30 cm).

In the experiment at 120° (heating lasted 40 hr) we obtained the following products: 1) unreacted divinyl and diisopropenyl; 2) divinyl dimer (126-130°) 50 g; 3) co-"dimer" (65-70° at 20 mm) 21 g; 4) high boiling products (diisopropenyl dimer) 4 g; 5) nondistilling polymer 3 g.

For the co-"dimer" we found:

B.p. 68-69° (20 mm), d^{20}_4 0.8426, n^{20}_4 1.4752, MR 45.54; calc. 45.25.

Found %: C 88.41, 88.31; H 11.85, 11.83. $C_{10}H_{16}$. Calculated %: C 88.16; H 11.84.

For determination of the composition we took a wide fraction, 63-70° (20 mm). We found 20% of dimer (II).

In the experiment at 170° (heating lasted six hours) we obtained the following products: 1) diisopropenyl 10 g; 2) divinyl dimer 61 g; 3) co-"dimer" (63-70° at 20 mm) 62 g; 4) high boiling products (chiefly diisopropenyl dimer) 15 g; 5) rubber-like polymer 30 g.

The co-"dimer" was repeatedly distilled to 83% passing in the range of 1°.

B.p. 68-69° (20 mm), d^{20}_4 0.8445, $n^{20}D$ 1.4762.

The content of carbon and hydrogen in the polymer agreed with the ratio $C_4H_6 : C_6H_{10} = 1 : 1\ 5-2.1$.

Found %: C 88.08, 88.38; H 11.91, 12.02.

Pure "dimers" (I) and (II) were obtained by the methods described previously [6, 7].

1-Vinyl-3,4-dimethyl-3-cyclohexene.

B.p.69.5-70.5° (20 mm), d^{20}_4 0.8448, $n^{20}D$ 1.4758, MR 45.47; calc. 45.25.

1-Methyl-1-isopropenyl-3-cyclohexene.

B.p. 63-64° (20 mm), d^{20}_4 0.8568, $n^{20}D$ 1.4768, MR 44.91; calc. 45.25.

SUMMARY

1. We have studied the reaction of co-"dimerization" of divinyl with diisopropenyl at 120 and 170°.

2. We have established that in this reaction, independent of temperature, there is formed a mixture of 1-vinyl-3,4-dimethyl-3-cyclohexene (80%) and 1-isopropenyl-1-methyl-3-cyclohexene (20%).

3. We have shown that the relative yield of mixed "dimers" increases with rising temperature.

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STUDIES IN THE FIELD OF COMPLEX LIPIDS

THE SYNTHESIS OF α-(α'-OLEOYL-β-STEAROYL)-CEPHALIN

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The natural phosphatides such as lecithin and cephalin, according to present results, are L-α-phosphatides [1-3] which include in their composition usually both saturated (palmitic, stearic) and unsaturated (oleic, linoleic, linolenic, arachidonic, etc.) acids [4].

An idea of the relative distribution of the residues of unsaturated and saturated acids on the α'- and β-hydroxyl groups in the different phosphatides [5-8] and therefore the synthesis of phosphatides with different acids would be of great value for establishing the structure of natural phosphatides and the study of their physiological properties.

The phosphatides synthesized up to the present time with unsaturated acids are either β-phosphatides [9] or include in their composition two residues of the same aliphatic acid [10, 11].

We have studied several variants of structure in α-phosphatides. According to the descriptions in the literature for the synthesis of α-cephalins there have been used as the starting substances either acylated α-halohydrins [12,13] or α,β-diglycerides [11, 14-16]. The first method cannot be used for synthesis of cephalins which contain unsaturated acid residues, due to the use of catalytic reduction for removal of the protective phenyl or carbobenzoyl groups. The possibilities of the second method are limited by the fact that until recently there was no known method for the synthesis of unsaturated α,β-diglycerides with different acid residues in definite positions.

At the basis of our scheme for the synthesis of α'-oleoyl-β-stearoyl-α-glycerylphosphorylethanol amine lies the stepwise construction of systems which contain the elements of natural α-(α'-oleoyl-β-stearoyl)cephalin (VI).

Infrared transmission spectra. 1) α-oleoyl-β-stearoylglycerol; 2) α-(α'- oleoyl-β-stearoyl)-cephalin.

By the action of α,α'-benzylidene glycerol (I) and stearoyl chloride we obtained the isomeric form of α,α'-benzylidene stearoylglycerol (II) with m.p. 58-59°.

Hydrolysis of α,α'-benzylidene stearoylglycerol (II) into β-stearoylglycerol (III) was carried out with boric acid in dioxane [17].

For preparing α-oleoyl-β-stearoylglycerol (IV) we used the reaction of acylation of β-stearoylglycerol (III) with oleoyl chloride. The structure of the synthesized α-oleoyl-β-stearoylglycerol (IV) was confirmed by its catalytic reduction to the known α,β-distearoylglycerol [1].

α-(α'-Oleoyl-β-stearoyl)cephalin (VI) was synthesized by us from α-oleoyl-β-stearoylglycerol (IV) by a modified method [18] consisting of two basic steps: 1) phosphorylation of α-oleoyl-β-stearoylglycerol with 2-phthalimidoethylphosphoryl dichloride [14], and 2) removal of the phthaloyl group of α'-oleoyl-β-stearoyl-α-glycerylphosphoryl-2'-hydroxyethylphthalimide by the action of hydrazine [11].

The infrared absorption spectra of α-oleoyl-β-stearoylglycerol and α-(α'-oleoyl-β-stearoyl)-cephalin were obtained on an IKS-11 spectrophotometer with an NaCl prism in the region 900-1900 cm^{-1} and with an LiF prism in the region 2800-3800 cm^{-1}. The spectra are given in the figure.

EXPERIMENTAL

α,α'-Benzylidene stearoylglycerol (II). To a solution of 20.2 g of α,α'-benzylidene glycerol [19] (m.p. 66.0-66.5°) in 50 ml of pyridine was added dropwise with cooling to 0° and stirring 31.2 g of stearoyl chloride. The mixture was heated to 35-40° with continuous stirring for 30 min and allowed to stand at 18-20° for 20 hr. The thick mass was heated to 40° and poured into 500 ml of water. The substance which precipitated was separated and recrystallized from alcohol (twice in 200 ml) and from a mixture of alcohol with petroleum ether (150 ml, 1 : 1 by volume). Yield of α,α'-benzylidene stearoyl glycerol 35.8 g (77.7%). M.p. 58-59°.

Found %: C 75.11; H 10.33. $C_{28}H_{46}O_4$. Calculated %: C 75.29; H 10.38.

β-Stearoylglycerol (III). a) A solution of 1 g of α,α'-benzylidene stearoyl glycerol (m.p. 58-59°) and 0.4 g of boric acid [17] in 8 ml of dioxane was heated to boiling for 10 min and the dioxane was quickly distilled off in a vacuum. The residue was heated at 125° for 15 min, cooled, and extracted with ether. The extract was washed with water and dried. After distillation of the solvent, the substance was recrystallized from ligroin (20 ml). We obtained 0.31 g (39%) of β-stearoylglycerol [20]. M.p. 74.0-75.0°.

b) Reduction of 14 g of α,α'-benzylidene stearoylglycerol (m.p. 58-59°) in the presence of palladium on activated charcoal in 100 ml of ethyl acetate [21] gave 9.2 g (81%) of β-stearoylglycerol. M. p. 75.0-75.4.

α-Oleoyl-β-stearoylglycerol (IV). To a solution of 5.65 g of β-stearoylglycerol in 100 ml of benzene and 3 ml of pyridine we added dropwise with stirring and heating to 30° a solution of 3.64 g of oleyl chloride (d_4^{20} 0.9145 n_D^{20} 1.4640, iodine number 83.5, calculated 84.36) in 40 ml of benzene. The reaction mass was cooled to 25° and left at this temperature for two hours, then diluted with 100 ml of ether. The precipitate of pyridine hydrochloride was separated, the filtrate was washed with water (four times with 30 ml) and dried with sodium sulfate. After distillation of the solvent, the resulting crystallized mass was dissolved in 80 ml of ligroin (b.p. 40-60°). When the solution cooled, crystals of unreacted β-stearoylglycerol precipitated and were filtered and washed with 20 ml of solvent. We isolated 1.68 g of β-stearoylglycerol. M.p. 75.0-75.4°. The mother liquor was freed from ligroin and the residue dried at 18-20° and 0.01 mm for two hours, then dissolved in 90 ml of 95% aqueous alcohol at 35°. The solution was decanted from the insoluble oily product and cooled to −15°. The precipitate of diglyceride was separated and dissolved in 10 ml of benzene. The benzene was distilled off in a vacuum and the resulting substance was dried for three hours at 18-20° and 0.01 mm. Yield 5.16 g (75.6%). M.p. 19.0-20.0°.

Found %: C 75.51; H 11.84; iodine number 42.0. $C_{39}H_{74}O_5$. Calculated %: C 75.19; H 11.97; iodine number 40.75.

α'-Oleoyl-β-stearoyl-α-glycerylphosphoryl-2'-hydroxyethylphthalimide (V). To a solution of 2.56 g of 2-phthalimidoethylphosphoryl dichloride [14] in 20 ml of chloroform we added with cooling to 7-9° and stirring 5.15 g of α-oleoyl-β-stearoylglycerol in 12 ml of cyclohexane and 2.25 ml of pyridine. The reaction mass was heated to 25° and stirred for two hours. Then at 8-10° was added 0.15 ml of water and the mixture was stirred for 30 min. The mixture was heated to 25°, stirred for 30 min, and diluted with 125 ml of ether. The ether solution was separated from the precipitate of pyridine hydrochloride, washed with 2 N sulfuric acid (70 ml), with a saturated water solution of sodium bicarbonate, and was dried with sodium sulfate. The solvent was removed and the residue was dried for two hours at 18-20° and 0.1 mm. The sirupy substance was dissolved in 130 ml of ligroin and allowed to stand for 15 hr at −15°. The slight precipitate was filtered off. After distillation of the solvent we obtained an almost colorless, sirupy substance. Yield 6.2 g (85.6%). After purification on a column with silicic acid [11] we obtained 5.5 g (76%) of analytically pure product.

d_4^{20} 1.037, $n^{20}D$ 1.4892, MR_D 243.8; calc. 242.36.

Found %: C 67.04, 67.27; H 9.48, 9.18. $C_{49}H_{82}O_{10}NP$. Calculated %: C 67.17; H 9.43.

α'-Oleoyl-β-stearoyl-α-glycerylphosphorylethanol amine, α-(α'-oleoyl-β-stearoyl)cephalin (VI). To a suspension of 2.26 g of α'-oleoyl-β-stearoyl-α-glycerylphosphoryl-2'-hydroxyethylphthalimide in 33 ml of ethylene glycol monomethyl ether we added in the course of 1.5 hr with cooling to 7-9° and stirring 5.15 ml of 0.5 N solution of sodium hydroxide. To the reaction mass at 7-9° we added 1.5 ml of 100% hydrazine hydrate and then with continuous stirring for three hours we raised the temperature to 60°. The mixture was cooled to 20° and the solution distilled off in a vacuum (1 mm). The residue was dissolved in 25 ml of anhydrous ether and after two hours the precipitate was separated. To the filtrate we added 1.3 ml of water, 1.3 ml of methyl alcohol, and then added 5 g of dry Amberlite IRC-50 (H⁺). The solution was shaken for 30 min, the resin was separated and washed with ether, the filtrate was evaporated at 18-20° and 0.1 mm. Yield 2.06 g. The product was purified chromatographically on a column with silicic acid [11]. We obtained a colorless substance. Yield 0.72 g (32%). M.p. 183-186°.

Found %: C 65.91; H 10.63; P 4.29; iodine number 32.8. $C_{41}H_{80}O_8NP$. Calculated %: C 66.01; H 10.80; P 4.15; iodine number 34.03.

SUMMARY

1. We have worked out a method for the synthesis of α,β-diglycerides with differing acid residues.

2. We have carried out the synthesis of α-(α'-oleoyl-β-stearoyl)cephalin.

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SYNTHETIC STUDIES IN THE FIELD OF FLAVONOIDS

II. SYNTHESIS OF 3-NITROFLAVANONE*

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In recent years studies in the field of flavonoids have taken a new direction in connection with the activity of various representatives of the flavonoids as vitamin P, and also their therapeutic and antioxidant properties [1, 2].

For the synthesis of flavonols, especially quercitin, the modified method of Allan-Robinson was used [3, 4]. It was desirable to expand the convenient and widely used method for the synthesis of flavanones by cyclization of o-hydroxyphenylstyryl ketones (2'-hydroxychalcones) to the preparation of flavonols.

In the present paper we describe the preparation of 3-nitroflavanone by a method which opens the way to synthesis of flavonol (VI) by chalcone-flavanone rearrangement of nitrochalcones of type (IV), where the polarization of the double bond by electrophilic substituents should permit closure of the pyrone ring [5].
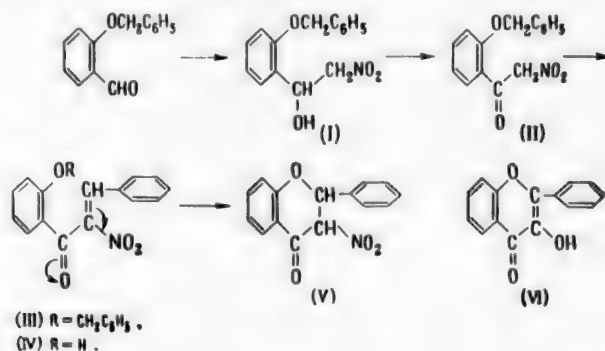
o-Benzoxyphenyl nitromethyl carbinol (I) was obtained in the condensation of O-benzylsalicylaldehyde with nitromethane under the influence of sodium methylate [6]. Oxidation of alcohol (I) into benzyloxy-ω-nitroacetophenone (II) with potassium bichromate in aqueous acetic acid, in distinction from the oxidation of phenyl-nitroethanol which goes easily under these conditions, occurs with a small yield, which shows spatial difficulties [7]. On the basis of the data from kinetics of oxidation by chromic acid in nonpolar solvents [8] the oxidation of o-benzyloxyphenyl-ω-nitroethanol (I) by potassium bichromate reaches a good yield in dioxane solution. For the later reaction of condensation with benzaldehyde we used as the catalyst ε-aminocaproic acid [9] and also other amino acids in which the amino and carboxyl groups occurred at the end of the carbon chain.

In an attempt to saponify the benzyl group by short heating of o-benzyloxyphenyl-ω-nitrostyryl ketone (III) in a mixture of glacial acetic acid and concentrated hydrochloric acid to obtain substance (IV) we isolated crystals of 3-nitroflavanone (V). The ultraviolet spectrum of the substance had two characteristic absorption maxima at 255 and 378 mμ, $E_{1cm}^{1\%}$ 388 and 518, respectively. For comparison we give the spectrum of the starting benzyloxy-nitrochalcone (Fig. 1, curve 2) and quercetin (Fig. 1, curve 3).

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*For Communication I, see [4].
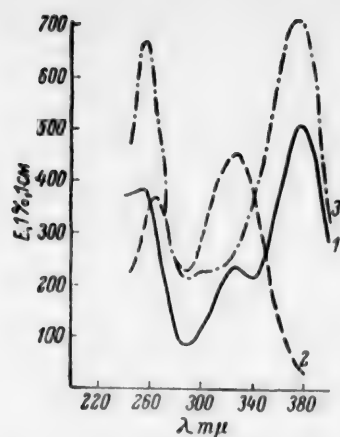
Fig. 1. Ultraviolet absorption spectra. 1) 3-Nitroflavanone in 96% alcohol, 2) o-benzyloxyphenyl-ω-nitrostyryl ketone in chloroform, 3) quercetin in 96% alcohol.

As we found, such a characteristic spectrum (maxima at 255 and 370 mμ, $E_{1\,cm}^{1\%}$ 500 and 651 respectively) occurred with the o-hydroxy-ω-nitroacetophenone which was specially isolated.

In comparison of the infrared absorption spectrum (Fig. 2) we found considerable change in the frequency of the valence symmetrical oscillation ν C = O. In the starting substituted nitrochalcone (III) it lies at 1666 cm^{-1}, a value close to the frequency for the unsubstituted chalcone (1659 cm^{-1}) [10]. In the 3-nitroflavanone it falls at 1706 cm^{-1}, against the usual value for unsubstituted flavanone of 1680 cm^{-1}. This corresponds to the loss of conjugation of the carbonyl group with the aliphatic double bond in closure of the pyrone ring.

EXPERIMENTAL

o-Benzyloxyphenylnitromethyl carbinol (I). To a solution of 5.0 g of o-benzyloxybenz aldehyde in 50 ml of absolute ether at −(5-0)° we added 1.44 g of nitromethane and then at −(10-5)° added a methanol solution of sodium alcoholate (from 0.54 g of sodium in 9 ml of methyl alcohol). The reaction mixture was stirred at −5° for 20 min, treated with a solution of 1.4 ml of acetic acid in 10 ml of absolute ether, and stirred for 30 min.
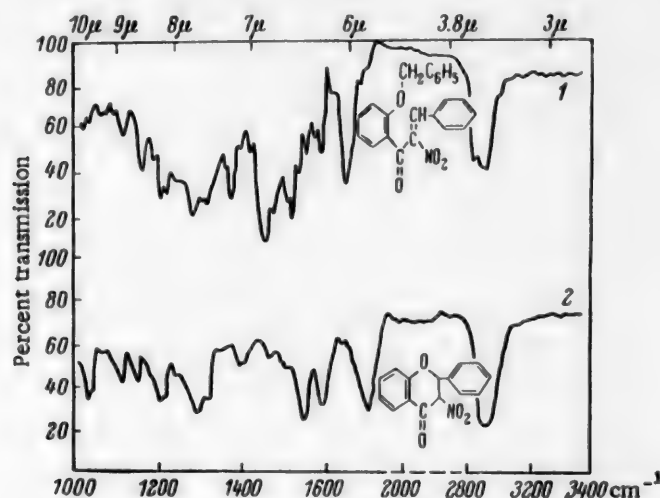
Fig. 2. Infrared absorption spectra. 1) o-Benzyloxyphenyl-ω-nitrostyryl ketone; 2) 3-nitroflavanone.

The precipitate was separated, washed with 15 ml of ether, the solvent was removed in a vacuum and the residue was crystallized from 25 ml of methyl alcohol. Colorless needles. Yield 5.61 g (86.9%). M.p. 65-66°.

Found %: C 66.49; H 5.69; N 4.66. $C_{15}H_{15}O_4N$. Calculated %: C 65.93; H 5.49; N 5.12.

o-Benzyloxy-ω-nitroacetophenone (II). To a solution of chromic mixture consisting of 4.9 g of potassium bichromate, 3.6 ml of concentrated sulfuric acid, and 20 ml of water, heated to 60°, we added 1.2 g of o-benzyloxyphenylnitromethyl carbinol in 60 ml of dioxane. The reaction mass was stirred for two hours at 55-60°, poured into 250 ml of water, and allowed to stand for a day. The solid substance which precipitated was separated, washed with 50 ml of water, and crystallized from 10 ml of methyl alcohol. Yield 0.7 g (58.7%).

M.p. 84-85°, λ_{max} 250 and 320 mμ; $E_{1\,cm}^{1\%}$ 420 and 278, respectively.

Found %: C 66.58; H 4.77; N 5.02. $C_{15}H_{13}O_4N$. Calculated %: C 66.42; H 4.8; N 5.16.

From the mother liquor after addition of 1 ml of water we isolated 0.35 g of o-benzyloxyphenylnitromethyl carbinol (nitroalcohol). The yield of o-benzyloxy-ω-nitroacetophenone (based on reacting nitroalcohol) was 83%.

o-Benzyloxyphenyl-ω-nitrostyryl ketone (III). In a round-bottomed flask with a water trap and reflux condenser we boiled for eight hours a mixture of 3.4 g of o-benzyloxy-ω-nitroacetophenone, 50 ml of anhydrous benzene, 2.66 g of benzaldehyde, and 0.16 g of ε-aminocaproic acid dissolved in 2 ml of glacial acetic acid. The benzene was distilled in a vacuum to 1/5 the original volume and cooled to 5-10°. The precipitate of crystals of o-benzyloxyphenyl-ω-nitrostyryl ketone was separated and washed with alcohol (3 times with 10 ml). Fine, colorless crystals. Yield 3.92 g (87%).

M.p. 151-152°, λ_{max} 265, 328 mμ, $E_{1cm}^{1\%}$ 373 and 465, respectively.

Found %: C 73.57; H 5.02; N 4.23. $C_{22}H_{17}O_4N$. Calculated %: C 73.53; H 4.76; N 3.9.

3-Nitroflavanone (V). A mixture of 3.8 g of o-benzyloxyphenyl-ω-nitrostyryl ketone, 38 ml of glacial acetic acid and 19 ml of concentrated hydrochloric acid was heated with continuous stirring for one hour on a water bath and allowed to stand for eight hours at 18-20°. The yellow crystals which precipitated were separated, washed with 10 ml of alcohol, and crystallized from 20 ml of alcohol. Bright yellow needles. Yield 0.93 g (32.6%).

M.p. 137.5-138°, λ_{max} 255, 328, and 378 mμ, $E_{1cm}^{1\%}$ 388, 239 and 518, respectively.

Found %: C 66.80; H 4.11; N 4.99. $C_{15}H_{11}O_4N$. Calculated %: C 66.91; H 4.09; N 5.2.

SUMMARY

1. 3-Nitroflavanone, an intermediate compound for the synthesis of flavonols, was obtained in the chalcone-flavanone rearrangement which occurs in the process of saponification of the benzyl group of o-benzyloxyphenyl-ω-nitrostyryl ketone.

2. We have described the synthesis of o-benzyloxyphenyl-ω-nitrostyryl ketone (o-benzyloxynitrochalcone).

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THE STUDY OF HYDROXYDIHYDROFURANS

VII. CONDENSATION OF 5,5-DIMETHYL-2,4-DIPHENYL-2-HYDROXY-2,5-DIHYDROFURAN WITH DIETHYL MALONATE

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It was shown previously that 2-hydroxy-2,5-dihydrofuran reacts with substances which contain mobile hydrogen atoms [1-3]. Continuing the study of the reactivity of 2-hydroxy-2,5-dihydrofurans, we have carried out the reaction of condensation of 5,5-dimethyl-2,4-diphenyl-2-hydroxy-2,5-dihydrofuran with diethyl malonate.

The reaction with malonic ester occurs by heating the mixture of reacting substances to 130-140° both without additions and in the presence of compounds with acid or basic character (glacial acetic and perchloric acid, piperidine). We found that the best results were obtained by addition of a small amount of piperidine to the reaction mixture.

The chief product of the reaction was an ester of a dibasic acid, diethyl(5,5-dimethyl-2,4-diphenyl-2,5-dihydrofuryl-2)malonate (II). We also isolated some of the partial monoethyl (5,5-dimethyl-2,4-diphenyl-2,5-dihydrofuryl-2)malonate (III), the formation of which can be explained by partial hydrolysis of the diethyl ester (II).

The diethyl ester (II) was hydrolyzed in acid and alkaline media. Under these conditions we found in the reaction products the monoethyl ester of the dibasic acid (III) and 5,5-dimethyl-2,4-diphenyl-2-hydroxy-2,5-dihydrofuran (I). The formation in the hydrolysis reaction of the hydroxydihydrofuran (I) indicates that the carbon-carbon bond which originates in the condensation is not strong, and easily splits under the influence of acids and bases. This finding agrees with the literature data [4, 5] and the results of our studies. We noted previously that the condensation product of 5,5-dimethyl-2,4-diphenyl-2-hydroxy-2,5-dihydrofuran with acetone was hydrolyzed under the influence of 10% sulfuric and 70% acetic acids with rupture of the carbon-carbon bond [2].

The splitting of the carbon-carbon bond in the condensation product was also observed by us in the action of a sulfuric acid solution of 2,4-dinitrophenylhydrazine on the diethyl ester (II). After a day there precipitated from the reaction mixture 2-methyl-3,5-diphenyl-3-penten-2-ol-5-one 2,4-dinitrophenylhydrazinohydrazone sulfate (IV) which we had obtained earlier by the action of a sulfuric acid solution of 2,4-dinitrophenylhydrazine on 5,5-dimethyl-2,4-diphenyl-2-hydroxy-2,5-dihydrofuran [6].

In the monoethyl ester of (5,5-dimethyl-2,4-diphenyl-2,5-dihydrofuryl-2)malonic acid (III), the carboxyl group is not very active: The substance dissolves slowly in alkali, and reacts sluggishly with soda and methylmagnesium iodide. The decreased activity of the acid group can evidently be explained by formation of intramolecular hydrogen bonds.

The semi-ethyl ester (III) is decarboxylated on melting and forms the ethyl ester of (5,5-dimethyl-2,4-diphenyl-2,5-dihydrofuryl-2)acetic acid (V). Alkaline hydrolysis of ester (V) gives (5,5-dimethyl-2,4-diphenyl-2,5-dihydrofuryl-2)acetic acid (VI),which was synthesized and described in previous work [7, 3].

All these transformations of the condensation product of 5,5-dimethyl-2,4-diphenyl-2-hydroxy-2,5-dihydrofuran with malonic ester are shown in the scheme.

(5,5-Dimethyl-2,4-diphenyl-2,5-dihydrofuryl-2)acetic acid (VI) can be obtained in another interesting way, by oxidation of the corresponding aldehyde (VII),which can be synthesized by condensation of hydroxydihydrofuran (I) with acetaldehyde. The condensation reaction was carried out by heating the substances in a sealed tube [5];

$$
\begin{array}{c}
\underset{\text{(VII)}}{\left[\begin{array}{c} C_6H_5-C=CH \\ (CH_3)_2C \quad C-C_6H_5 \\ \quad O \quad CH_2 \\ \quad CHO \end{array}\right]}
\xleftarrow{}
\underset{\text{(I)}}{\begin{array}{c} C_6H_5-C=CH \\ (CH_3)_2C \quad C-C_6H_5 \\ \quad O \quad OH \end{array}}
\xrightarrow{}
\underset{\text{(II)}}{\begin{array}{c} C_6H_5-C=CH \\ (CH_3)_2C \quad C-C_6H_5 \\ \quad O \quad CH-COOC_2H_5 \\ \quad COOC_2H_5 \end{array}} + \text{(III)}
\end{array}
$$

$$
\underset{\text{(VI)}}{\begin{array}{c} C_6H_5-C=CH \\ (CH_3)_2C \quad C-C_6H_5 \\ \quad O \quad CH_2 \\ \quad COOH \end{array}}
\xleftarrow{}
\underset{\text{(V)}}{\begin{array}{c} C_6H_5-C=CH \\ (CH_3)_2C \quad C-C_6H_5 \\ \quad O \quad CH_2 \\ \quad COOC_2H_5 \end{array}}
\xleftarrow{}
\underset{\text{(III)}}{\begin{array}{c} C_6H_5-C=CH \\ (CH_3)_2C \quad C-C_6H_5 \\ \quad O \quad CH-COOH \\ \quad COOC_2H_5 \end{array}} + \text{(I)}
$$

$$
\text{(II)} \rightarrow
\underset{\text{(IV)}}{\begin{array}{c} C_6H_5 \\ (CH_3)_2C-C-CH_2-C-C_6H_5 \\ \quad OH \quad NH \qquad N \\ \qquad NH \qquad NH \\ \qquad C_6H_3(NO_2)_2 \quad C_6H_3(NO_2)_2 \end{array}} \cdot 2H_2SO_4
$$

however, we could not isolate the aldehyde in pure form from the reaction products, and we also could not obtain derivatives of the carbonyl group. The condensation product without purification was oxidized with silver oxide in alkaline solution [8]. In the oxidation we obtained an acid identical with the substance formed in the hydrolysis of ester (V) and with the substance obtained earlier by condensation of hydroxydihydrofuran (I) with acetic anhydride [3].

EXPERIMENTAL

Condensation of 5,5-dimethyl-2,4-diphenyl-2-hydroxy-2,5-dihydrofuran with malonic ester. A mixture of 7 g of 5,5-dimethyl-2,4-diphenyl-2-hydroxy-2,5-dihydrofuran (I) and 15 ml of malonic ester to which 6 drops of piperidine had been added was heated for two hours on an oil bath at 130-140°. The light yellow solution which formed was diluted with ether and dried with sodium sulfate. After removal of the ether and vacuum distillation of the excess malonic ester (we collected 8 ml with b.p. 81-84° at 2 mm) the thick yellow oil which remained crystallized almost completely. We isolated 9 g of nonhomogeneous crystals. By numerous recrystallizations from alcohol we separated the mixture into two substances. We obtained 6.8 g (63.5%) of the diethyl ester of (5,5-dimethyl-2,4-diphenyl-2,5-dihydrofuryl-2)malonic acid (II) with m.p. 81-82° (from 50% alcohol) and 1.2 g (12%) of the monoethyl ester of (5,5-dimethyl-2,4-diphenyl-2,5-dihydrofuryl-2)malonic acid (III) with m.p. 150-151° (from alcohol).

The diethyl ester (II) crystallized in large, colorless prisms, soluble in methyl and ethyl alcohols, ether, and benzene; insoluble in water.

Found %: C 73.87, 73.66; H 7.15, 6.99. M 399. $C_{25}H_{28}O_5$. Calculated %: C 73.51; H 6.91. M 408.2.

The monoethyl ester (III) was isolated in the form of fine needles, soluble in benzene and hot alcohol; poorly soluble in cold alcohol and in ether. At the melting point it decomposed with evolution of gas bubbles.

Found %: C 72.79, 72.74; H 6.41, 6.72; OC_2H_5 11.94. M 374. Acid equiv. 377.2. $C_{23}H_{24}O_5$. Calculated %: C 72.62; H 6.36; OC_2H_5 11.84. M 380.4. Acid equiv. 380.4.

Hydrolysis of diethyl (5,5-dimethyl-2,4-diphenyl-2,5-dihydrofuryl-2)malonate. a) In acid medium. To a solution of 2 g of substance (II) with m.p. 81-82° in 30 ml of methyl alcohol we added a solution of 2 ml of concentrated hydrochloric acid (d 1.18) in 10 ml of methyl alcohol and heated the mixture on the boiling water bath for 1.5 hr. Then the reaction mixture was poured into water and extracted with ether. The water-alcohol solution after removal of the ether had a greenish color which disappeared when soda was added. An ether extraction was also made of the neutralized solution. To the residue obtained after removal of the ether from the extract of the solution neutralized by soda we added several drops of 60% $HClO_4$. A precipitate of 0.3 g of a yellow perchlorate with m.p. 205-206° came down and gave no melting point depression in a sample mixed with the perchlorate of 5,5-dimethyl-2,4-diphenyl-2-hydroxy-2,5-dihydrofuran obtained previously [1].

The ether extract from the acid solution contained a thick yellow oil from which at once after distillation of the ether needle shaped crystals with m.p. 148-149° began to separate. The substance gave no melting point depression with compound (III) obtained in the condensation. We isolated 0.2 g (10%). The remaining oily liquid crystallized after several days. We obtained 0.8 g (56%) of a substance with m.p. 96-97° (from a mixture of ether and ligroin) which gave no melting point depression with 5,5-dimethyl-2,4-diphenyl-2-hydroxy-2,5-dihydrofuran (I).

b) In an alkaline medium. The diethyl ester (II) with m.p. 81-82°, 1.6 g, was dissolved in 20 ml of ethanol, and 0.32 g of sodium hydroxide in 20 ml of ethanol was added; the mixture was heated two hours on a boiling water bath and then poured into water. From the water-alcohol solution (with an alkaline reaction) an ether extract was made and this was washed with dilute hydrochloric acid; the acid solution was neutralized with soda and treated with ether. From the ether extract we isolated a little liquid which on addition of $HClO_4$ gave the perchlorate of the 2-hydroxy-2,5-dihydrofuran (I) with m.p. 203-204° [1].

The oily liquid obtained after distillation of the ether from the extract of the alkaline solution (1.1 g) soon partly crystallized. We isolated 0.2 g of needle shaped crystals with m.p. 148-150°. The substance gave no melting point depression in a sample mixed with the monoethyl ester (III). The water-alcohol solution after neutralization with hydrochloric acid was also treated with ether. We obtained from the ether extract about 0.2 g of monoethyl ester (III) with m.p. 149-150°.

Action of sulfuric acid solution of 2,4-dinitrophenylhydrazine on the diethyl ester of (5,5-dimethyl-2,4-diphenyl-2,5-dihydrofuryl-2)malonic acid (II). To a solution of 0.5 g of diethyl ester (II) in 15 ml of ethanol we added a sulfuric acid solution of 2,4-dinitrophenylhydrazine [9]. After a day, a light yellow precipitate appeared in the solution in the form of fine needles which gradually filled the whole liquid. The precipitate was filtered off, washed with aqueous alcohol and water, and dried in a desiccator. When the precipitate was washed, it decreased in volume and became dark yellow. M.p. 154-156° (decomp.). A sample mixed with 2-methyl-3,5-diphenyl-3-penten-2-ol-5-one 2,4-dinitrophenylhydrazinohydrazone previously obtained [6] gave no melting point depression. The precipitate was partly recrystallized from glacial acetic acid. It formed dark yellow crystals with m.p. 163-165° (decomp.); a sample mixed with 2-methyl-3,5-diphenyl-3-penten-2-ol-5-one 2,4-dinitrophenylhydrazone [6] showed no melting point depression.

Decarboxylation of monoethyl ester of (5,5-dimethyl-2,4-diphenyl-2,5-dihydrofuryl-2)malonic acid. The monoethyl ester (III) with m.p. 150-151°, 1.5 g, was heated for one hour on a metal bath at 160-170°. At first the heating caused strong foaming. When the residue was cooled, it was diluted with ether. After removal of the ether there remained a thick yellow liquid with a pleasant odor, which did not crystallize after three months. The substance was distilled in a vacuum. We obtained 1 g (75%) of ethyl (5,5-dimethyl-2,4-diphenyl-2,5-dihydrofuryl-2)-acetate (V) with b.p. 188-190° (2 mm).

Found %: C 78.74, 78.69; H 7.14, 7.15; OC_2H_5 13.2. M 335. $C_{22}H_{24}O_3$. Calculated %: C 78.54; H 7.19; OC_2H_5 13.69. M 336.4.

Hydrolysis of ethyl (5,5-dimethyl-2,4-diphenyl-2,5-dihydrofuryl-2)acetate (V). The ethyl ester (V), 0.5 g, was added to a solution of 0.18 g of sodium hydroxide in 20 ml of ethanol. The mixture was heated for 2.5 hr on a boiling water bath, then poured into 30 ml of water. The water-alcohol solution was extracted with ether and from the extract we separated a small amount of tarry substance. The water-alcohol solution was evaporated to small volume and acidified. The substance which precipitated was dissolved in ether. From the ether extract we obtained 0.35 g of acid (VI) with m.p. 137-138° which showed no melting point depression with (5,5-dimethyl-2,4-diphenyl-2,5-dihydrofuryl-2)acetic acid obtained previously by condensation of 5,5-dimethyl-2,4-diphenyl-2-hydroxy-2,5-dihydrofuran (I) with acetic anhydride [3].

Condensation of 5,5-dimethyl-2,4-diphenyl-2-hydroxy-2,5-dihydrofuran (I) with acetaldehyde. Ten g of the hydroxydihydrofuran was mixed with 15 ml of freshly distilled acetaldehyde and heated in a sealed tube on a boiling water bath for four hours. Ten ml of acetaldehyde was distilled off from the light yellow solution which was formed, and the residue partly crystallized. The crystals were 5,5-dimethyl-2,4-diphenyl-2-hydroxy-2,5-dihydrofuran (mixed sample). We collected 5.4 g. The remaining clear rose colored oil (4.2 g) did not crystallize on long standing. Attempts to distill the reaction product in a vacuum did not succeed.

Oxidation of the condensation product of the hydroxydihydrofuran (I) with acetaldehyde. A solution of 1.7 g of the oil obtained in the condensation and 20 ml of alcohol were poured into a solution of 2.4 g of silver nitrate in

50 ml of alcohol and to the resulting mixture during the course of 0.5 hr was added a solution of 1.2 g of sodium hydroxide in 40 ml of alcohol. The reaction mixture was stirred for 10 hr at room temperature and then allowed to stand overnight. On the next day the precipitate was filtered off and the excess alcohol distilled. Water was added to the residue to dissolve the precipitate and an ether extract was made from which we isolated 0.55 g of a thick yellow oil. The water solution was acidified and treated with ether. After removal of the solvent we obtained 0.75 g of acid (VI) with m.p. 138-139°.

SUMMARY

1. We have carried out the condensation of 5,5-dimethyl-2,4-diphenyl-2-hydroxy-2,5-dihydrofuran with diethyl malonate. We have isolated the diethyl and monoethyl esters of (5,5-dimethyl-2,4-diphenyl-2,5-dihydrofuryl-2)malonic acid.

2. We have found that diethyl (5,5-dimethyl-2,4-diphenyl-2,5-dihydrofuryl-2)malonate in the presence of acids and alkalis decomposes with splitting of the carbon-carbon bond which formed in the condensation reaction.

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THE PREPARATION OF γ,γ-DIMETHYLALLYL AND ISOPROPENYLETHYL ALCOHOLS FROM THE CONDENSATION PRODUCT OF ISOBUTYLENE WITH FORMALDEHYDE

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Biochemical investigations have shown that 3-methyl-Δ^3-butenyl-1-pyrophosphate ("active isoprene") plays a large part in the biosynthesis of terpenes, carotenoids, and steroids [1, 2]. From the chemical point of view this pyrophosphate, like the pyrophosphate ester of the isomeric γ,γ-dimethylallyl alcohol, has not been sufficiently studied.

In the present paper we study the possibility of obtaining γ,γ-dimethylallyl and isopropenylethyl (3-methyl-3-buten-1-ol) alcohols from the condensation product of isobutylene with formaldehyde, 4,4-dimethyl-1,3-dioxane (I).

In the condensation of isobutylene with formaldehyde in the presence of a water solution of sulfuric and phosphoric acids or boron fluoride, the chief product of the reaction is 4,4-dimethylmetadioxane (I) [3-5].

In the action on dioxane (I) of acetic anhydride and catalytic amounts of concentrated sulfuric acid under the conditions which we have found [6] there is an energetic reaction accompanied by heating. The diacetate (II) which is formed gives, when the reaction mass is distilled, a mixture of acetates of methylbutenols (III and IV).
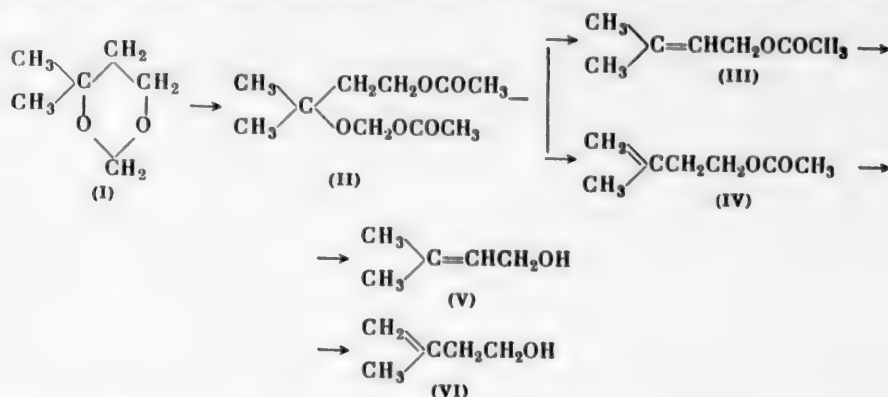
When the acetates are heated with aqueous alkali, alcohols are obtained which are separated as azeotropes with water. By salting out and later fractionation we obtain isopropenylethyl and γ,γ-dimethylallyl alcohols.

The structures of the isolated alcohols are confirmed by the combination scattering spectra. The valence symmetrical oscillation of the secondary-tertiary double bond of γ,γ-dimethylallyl alcohol (3-methyl-2-buten-1-ol) (V) is characterized by the frequency 1670.5 cm^{-1}. In the spectrum of isopropenylethyl alcohol (3-methyl-3-buten-1-ol) (VI) there is a band at 1643.3 cm^{-1} which characterizes the valence symmetrical oscillation of the double bond in the system.

The authors express thanks to L. V. Luk'yanova for obtaining the combination scattering spectra and participating in their interpretation.

EXPERIMENTAL[*]

Diacetate (II). To 116 g of 4,4-dimethyl-1,3-dioxane during 10-15 min we added with stirring a mixture of 110 ml of acetic anhydride and 0.1 ml of sulfuric acid. Stirring was continued until the temperature of the liquid began to fall. The maximum temperature which was reached due to spontaneous heating was 58-63°. The color of the liquid changed from light yellow to dark red. The reaction mixture was heated for one hour on the boiling water bath, then at 15-20 mm we distilled off the unreacted starting substances. For isolation of the diacetate (II) the liquid was neutralized with a water solution of sodium bicarbonate and distilled in a vacuum. We obtained diacetate (II) as a clear, colorless liquid.

B.p. 133-135° (10 mm), d_4^{20} 1.0631, $n^{20}D$ 1.4320, MR_D 53.220. $C_{10}H_{18}O_5$. Calculated 53.331.

Acetates of methylbutenols (III and IV). If it was not required to isolate diacetate (II), then after distillation of unreacted starting substances, the liquid, which contained sulfuric acid, was distilled at 65-75° (15-20 mm). The resulting acetates of methylbutenols and acetic acid were collected in a receiver and formaldehyde was absorbed by water in a succession of flasks. The end of the reaction of splitting was determined by the beginning of evolution of high boiling byproducts; then the temperature of the vapors rose to 90-100° (15 mm).

The collected distillate was washed with water for full removal of acetic acid and traces of the starting substances and also formaldehyde; the organic layer was neutralized with sodium bicarbonate, dried with magnesium sulfate, and distilled. We obtained the acetates of methylbutenols as clear, colorless liquids. The yield of mixed esters was 81.8 g (63.8% of the starting dimethyldioxane). By rectification we obtained the acetates of isopropenyl-ethyl and γ,γ-dimethylallyl alcohols in the ratio 68 : 32.

Acetate of isopropenylethyl alcohol (IV). B.p. 144-145° (753 mm), d_4^{20} 0.9104, $n^{20}D$ 1.4210, MR_D 35.711. $C_7H_{12}O_2$. Calculated 35.713.

Acetate of γ,γ-dimethylallyl alcohol (III). B.p. 148-150° (753 mm), d_4^{20} 0.9169, $n^{20}D$ 1.4270, MR_D 35.905. $C_7H_{12}O_2$. Calculated 35.713.

The mixture of acetates was distilled with steam at 94-95°. The solubility in water of the mixture of acetates was 0.5%; the solubility of the monoacetates in water was 0.4-0.5%.

Unsaturated alcohols C_5H_9OH. a) Isopropenylethyl alcohol (VI). We mixed 128 g of acetate (IV) (b.p. 144-145° at 753 mm) with four times the amount by volume of aqueous 20% sodium hydroxide. Saponification was carried out with intensive stirring of the boiling mixture for one hour. At the end of the saponification the azeotrope of the resulting alcohol was distilled in a column with ten theoretical plates; the organic layer was separated in the distillate, and from the water layer a further amount was obtained by salting out with potash; it was dried with ignited potassium carbonate and distilled. We obtained isopropenyl alcohol with a yield of 82.04 g (95.4%).

B.p. 130-132°, d_4^{20} 0.8653, $n^{20}D$ 1.4340, MR_D 26.176. $C_5H_{10}O$. Calculated 26.348.

b) γ,γ-Dimethylallyl alcohol (V). We mixed 128 g of acetate (III) (b.p. 148-150° at 753 mm) with four times the amount by volume of aqueous 20% sodium hydroxide and treated it as in the previous experiment. We obtained γ,γ-dimethylallyl alcohol. Yield 77.4 g (90.0%).

B.p. 139-140°, d_4^{20} 0.8616, $n^{20}D$ 1.4410, MR_D 26.383. $C_5H_{10}O$. Calculated 26.348.

Identification of the Unsaturated Alcohols C_5H_9OH

a) Acetylation of isopropenylethyl alcohol. We mixed 20.4 g of alcohol (b.p. 130-132°) with 30.0 g of acetic anhydride in the presence of 2.5 g of freshly melted sodium acetate for ten hours and allowed the mixture to stand for 12 hr. It was diluted with water, the organic substance was separated, the water layer was salted out with potash, the combined organic substrates were dried with anhydrous sodium sulfate. Distillation separated the acetate of iso-propenylethyl alcohol. Yield 24.88 g (81.9%).

B.p. 144-145° (753 mm), d_4^{20} 0.9104, $n^{28}D$ 1.4210. M (by saponification number) 127.56. $C_5H_{10}O$. Calculated 128.210.

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[*] A. I. Orekhova and I. S. Grishina took part in this work.

b) _Acetylation of γ,γ-dimethylallyl alcohol._ We mixed 20.4 g of alcohol (b.p. 139-140°) with 30 g of acetic anhydride in the presence of 2.5 g of freshly fused sodium acetate and treated as in the previous experiment We obtained the acetate of γ,γ-dimethylallyl alcohol. Yield 24.2 g (79.7%).

B.p. 148-150° (753 mm), d^{20}_4 0.9169, n^{20}D 1.4270.

SUMMARY

1. From the reaction product of isobutylene with formaldehyde, 4,4-dimethyl-1,3-dioxane, by heating with acetic anhydride in the presence of sulfuric acid we obtained a mixture of acetates of isopropenylethyl and γ,γ-dimethylallyl alcohols.

2. On saponification of the isolated rectified acetates we obtained the pure isopropenylethyl and γ,γ-dimethylallyl alcohols.

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ADDITION OF FULL ESTERS OF PHOSPHOROUS
AND PHOSPHINIC ACIDS TO CONJUGATED SYSTEMS

XI. REACTION OF TRIALKYL PHOSPHITES WITH p-QUINONES

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In our recently published work we have described the reaction of trialkyl phosphites with various π, -conjugated systems [1] and some compounds which have π ,π , -conjugation [2]. It seemed interesting to us also to study the action of trialkyl, phosphites on other compounds which have π, π, π -conjugation, for example, on p-quinones. A report of the first experiments in this field was published previously by us [3].

According to the literature in the addition of triphenylphosphite to p-benzoquinone there is formed compound (I), and on addition to chloroanil, (II) [4,5]. Triethylphosphite adds to chloroanil [6], forming compound (III).

In a previous report in the literature [7] there is described the reaction of trialkyl phosphites with p-benzoquinone and some substituted p-benzoquinones, where the addition products of trialkylphosphites to p-benzoquinone were ascribed the structure (IV).
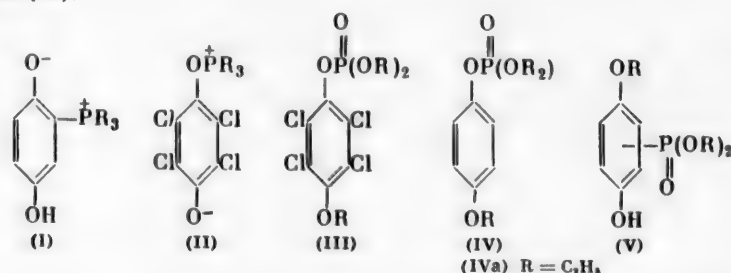
We have studied the reaction of trialkylphosphites with p-benzoquinone and 1,4-naphthoquinone. The resulting products of the addition of trialkylphosphites to p-benzoquinone are colorless, glycerol-like liquids, insoluble in water, easily soluble in alcohol, acetone, and benzene.

On the basis of a study of the addition products of triethylphosphite to p-benzoquinone, in our previously published work we expressed the idea [3] that it had the structure (V) (R = C_2H_5). This idea occurred to us on the basis of the fact that the product which we isolated differed in its constants from the isomeric phosphate (IVa) obtained by a counter synthesis according to the scheme:

$$(C_2H_5O)_2PCl + HO-\!\!\left\langle\!\!\!\bigcirc\!\!\!\right\rangle\!\!-OC_2H_5 \rightarrow (C_2H_5O)_2PO-\!\!\left\langle\!\!\!\bigcirc\!\!\!\right\rangle\!\!-OC_2H_5 \quad (IVa)$$
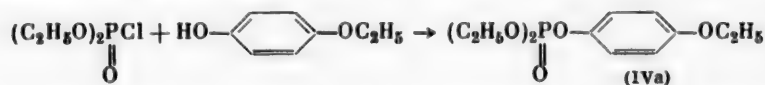
In a recently published, more detailed report there is new evidence to favor type (IV) and not the hydroquinone phosphonate (V) [8].

We have several times repeated the reaction of triethylphosphite with p-benzoquinone and under all conditions obtained the earlier described compound,which differs in its constants from the substance synthesized byRamirez and Dershowitz (compound A, Table 1). It gives a qualitative reaction for the hydroxyl group (the quantitative hydroxyl content is given in Table 1). The infrared spectrum of substance A has a strong and wide absorption band in the region of 3400 cm^{-1}, which corresponds to strongly associated hydroxyl groups.

TABLE 1. Constants of Compound A, B, and C

No.	Substance	B.p. (pressure in mm)	n_D^{20}	d_4^{20}	% P found	% P calc.	% OH
1	A	162—163° (3)	1.4868	1.1531	10.97	11.31	4.60
2	B	165—167 (4)	1.4830	1.1465	11.33	11.31	None
3	C	166—167 (4)	1.4830	1.1451	11.28	11.31	None

In distinction from our experiments, Ramirez and Dershowitz [8] washed the reaction product of p-benzoquinone and triethylphosphite with an alkaline solution before distilling in a vacuum. We have repeated their experiment exactly and obtained a product which is completely identical with that described by them (substance B, Table 1). It does not give a qualitative test for the hydroxyl group; absorption bands in the infrared spectrum in the region of $3400\ cm^{-1}$ are absent. In comparing the infrared spectra of compounds A and B, we note their great similarity; most of the absorption bands are close or identical in their positions, but differ somewhat in their intensities.

As a result of repeated counter synthesis by the scheme described above we have isolated, after careful purification, a product entirely identical with that obtained by Ramirez and Dershowitz (compound C, Table 1), whose infrared spectrum is completely identical with the infrared absorption spectrum of substance B.

Our results, together with the data from [8], confirm that these authors were dealing with diethyl (p-ethoxyphenyl)phosphate.

We can assume that under the action of alkali there is a rearrangement of the ester of hydroquinone phosphonic acid (V) into the isomeric phosphate (IV). The possibility of conversion of some esters of α-hydroxyalkylphosphonic acids into the isomeric phosphates under the influence of alcoholic solutions of sodium alcoholates has been shown in our work [9].

Attempts to carry out the conversion of substances A and B by heating with alcoholic solutions of sodium alcoholates did not succeed, however. When we washed substance A with alkaline water we obtained substance B, and the quantity of the product was markedly decreased.

In the course of further study we showed that in carrying out the reaction of triethylphosphite with p-quinone under certain conditions there was formed a crystalline complex with structure (VI).

$$OH\ldots O=P(OC_2H_5)_2O-\langle\ \rangle-OC_2H_5$$

$$OH\ldots O=P(OC_2H_5)_2O-\langle\ \rangle-OC_2H_5$$

(VI)
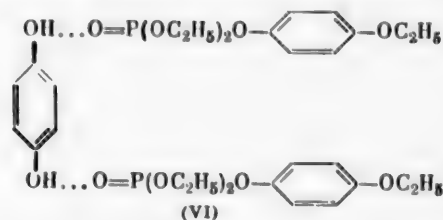
Since under all conditions in the reaction of triethylphosphite and p-benzoquinone there was formation of some quinhydrone, we can assume that some quantity of complex (VI) was formed in each case. Actually, with strong cooling of product A we have observed precipitation of crystals which were identified as complex (VI). The content of hydroxyl groups in the remaining liquid product was lowered considerably (up to 1-2%); its constants approached the constants of pure phosphate B.

Thus we established that our substance A is a mixture of substance B and complex (VI), not separated by distillation. For a final test of this conclusion we dissolved an equimolecular amount of complex (VI) in substance B. When this mixture was distilled, only one fourth of the amount of crystals used distilled at the temperature used, and we obtained a fraction identical in constants and properties with compound A.

When we carried out the reaction of triethylphosphite with p-benzoquinone in moist benzene, besides the main product of the reaction we obtained a crystalline substance which contained phosphorus and gave a qualitative reaction

TABLE 2

No.	Formula	B.p. (pressure in mm)	n^{20}_D
1	$CH_3O\langle\rangle OP(OCH_3)_2$ $\parallel$ O	162—164° (6)	1.4950
2	$C_2H_5O\langle\rangle OP(OC_2H_5)_2$ $\parallel$ O	162—163 (3)	1.4830
3	$n\text{-}C_3H_7O\langle\rangle OP(OC_3H_7\text{-}n)_2$ $\parallel$ O	175—176 (2)	1.4790
4	$(C_2H_5O)_3P$ (quinone structure)	M.p. 72—73° (with decomp.)	—
5	$OH\ldots O=P(OC_2H_5)_2O\langle\rangle OC_2H_5$ $OH\ldots O=P(OC_4H_9)_2O\langle\rangle OC_2H_5$	M.p. 39—42° 197—198 (12)	—
6	$C_2H_5O-\langle\rangle-OP(OC_2H_5)_2$ $\parallel$ O	166—167 (4)	1.4830
7	$O-P(OC_2H_5)_2$ $\parallel$ O ... OC_2H_5	200—204 (2)	1.5480
8	$O-P(OC_3H_7\text{-}n)_2$ $\parallel$ O ... $OC_3H_7\text{-}n$	212—215 (2)	1.5341
9	$O-P(OCH_2)_2$ $\parallel$ O ... OCH_3	M.p. 56—58° 201—203 (4)	—

for the hydroxyl group. The analytical data for these crystals corresponded to the addition product of two molecules of diethyl(p-ethoxyphenyl)phosphate with a molecule of hydroquinone. Such a complex compound has been described in the literature [10]. For the purpose of identifying the above complex (VI) it was prepared by the action of water on an alcohol solution of substance (IVa) and hydroquinone in the ratio 2 : 1. The complex (VI) was soluble in ether, acetone, alcohol, and benzene, insoluble in water. It was not decomposed by heating or boiling in various solvents. Under the influence of weakly alkaline water solutions there was destruction of the complex; the hydroquinone dissolved in the alkaline water, and the phosphate (IVa) separated as a liquid not miscible with water.

The ability of this complex compound to distill without evident decomposition is very surprising. It distills entirely within one degree without the least evolution of hydroquinone on the walls of the condenser or receiver and boils about 40° higher than hydroquinone and 15° higher than phosphate (IVa). Its mixture with phosphate (IVa) is not decomposed on distillation.

d^{20}_4	Empirical formula	%P		Yield, %
		found	calc.	
1.2423	$C_9H_{13}O_5P$	13.18	13.27	51.0
1.1465	$C_{12}H_{19}O_5P$	11.30	11.31	67.6
1.1416	$C_{15}H_{25}O_5P$	9.99, 10.15	9.81	51.2
—	$C_{24}H_{19}O_5P$	7.45	7.41	12.5
—	$C_{30}H_{44}O_{12}P_2$	9.52	9.42	21.8
1.1451	$C_{12}H_{19}O_5P$	11.22, 11.36	11.31	42.6
1.1863	$C_{16}H_{21}O_5P$	9.41	9.56	54.2
1.1316	$C_{19}H_{27}O_5P$	8.41, 8.65	8.46	41.7
—	$C_{13}H_{15}O_5P$	10.47	10.98	24.0

When the reaction of triethylphosphite with p-benzoquinone is run in anhydrous alcohol we obtain as the chief products hydroquinone, triethylphosphate, and small amounts of complex (VI). When the reaction is carried out in the presence of acetic acid the same were obtained, chiefly complex (VI).

Triphenylphosphite, in distinction from trialkylphosphites, does not react with p-benzoquinone at room temperature. On long heating in benzene solution triphenylphosphite and p-benzoquinone form an unstable product which is quickly converted in air into a dark red tar with a phenolic odor. On heating, the reaction of alcohol and water also cause tarring acoompanied by the evolution of phenol.

The chemical properties of the substance, and also the analytical data (see Table 2) suggest that it is an intermediate product of addition of triphenylphosphite to p-benzoquinone and probably has the structure (VIIIa) or (VIIIb).

The addition of trialkylphosphites to 1,4-naphthoquinone occurs less energetically. The resulting addition products are also colorless, glycerol-like liquids, insoluble in organic solvents. Their physical constants are given in Table 2 (compounds 7, 8, 9). They do not contain hydroxyl groups, evidently because of addition of the trialkylphosphite to 1,4-naphthoquinone in the same way as in the reaction with p-benzoquinone to form the corresponding phosphates, and not the phosphonic esters. Triphenylphosphite does not react with 1,4-naphthoquinone even after long heating.

Ramirez and Dershowitz [6] noted the paramagnetic resonance absorption from free radicals in the course of the chemical reaction of chloroanil and triethylphosphite.

We have carried out a corresponding study to explain the mechanism of the chemical reaction of full esters of phosphorous acid with p-quinones. Our study shows that at a frequency v 9680 Mc at the beginning of the chemical reaction of chloroanil with triethylphosphite there is a single line or resonance absorption with a width H 2.5 gauss (Fig. A). During the reaction the intensity of this line gradually decreases and the line splits into two superfine components (SFC) related to the action of the unpaired electron on the spine of the nucleus P^{31} (J 1/2). The distance between the peaks of SFC equals 2 gauss (Fig. B). At the end of the chemical reaction the line of paramagnetic resonance is not found.

a   b

With the help of the standard free radical α,α-diphenyl-β-picrylhydrazyl we determined the number of paramagnetic centers occurring at the beginning of the reaction of chloroanil with triethylphosphite; it equalled $6 \cdot 10^{17}$ spines in a volume of 0.10 ml of solution. The high concentration of free radicals in this reaction suggests that their appearance is connected with the main direction of the reaction and not with a side process.

Study of the reaction of trialkylphosphites with p-benzoquinone and 1,4-naphthoquinone did not lead to detection of a line of resonance absorption. Evidently unsubstituted quinones, as distinct from chloroanil, do not undergo the Arbuzov rearrangement by the free radical mechanism, or else the lifetime of the free radicals formed in the reaction is very short. The possibility is not excluded of the occurrence of these reactions by an ion chain mechanism.

The ability of the trialkylphosphites to add in the 1-6 position of the conjugated quinone system is very unexpected, since the phosphines and most other nucleophilic reagents add to unsubstituted p-quinones in the 1-4 position. Probably here there is an analogy with the reaction of trialkylphosphites with α-halocarbonyl compounds [1]; in this case also there occurs addition of nucleophilic phosphorus to oxygen. Most authors who have studied this reaction conclude that here there is first formed a bond $P-C-O^-$, which rearranges during the reaction to the bond $P-O-C$ [1]. It seems likely to us that in the reaction of trialkylphosphites with quinones at first there is formed a $P-C$ bond and then occurs rearrangement to the isomeric phosphate, for example, in the following way:

(VIIIa)   (VIIIb)   (IV)

(IV)

1074
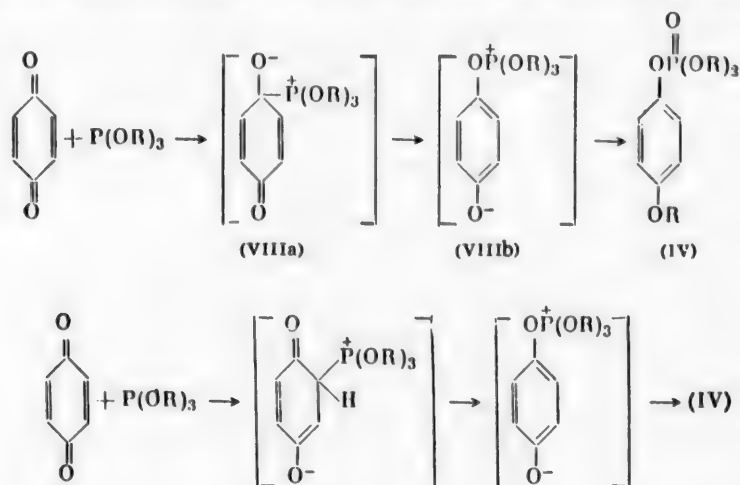
Stable intermediate products of the Arbuzov rearrangement are not formed in this case, in distinction from the reaction of α-diketones with trialkylphosphites [11]; only in addition of triphenylphosphite is a very unstable intermediate product obtained.

EXPERIMENTAL

Addition of Triethylphosphite to p-Benzoquinone

a) To an absolutely dry benzene solution of 16.2 g of benzoquinone was added by drops with strong stirring 25 g of triethylphosphite. The temperature rose to 60°, and the solution became red-brown. To prevent further heating, the reaction mixture was cooled with ice water. Spontaneous heating stopped and the solution became light tea colored. The reaction mass was left at room temperature until the next day. As a result of vacuum distillation we obtained 24 g (75.6%) of substance A (Table 1).

After washing this product with an aqueous solution of 10% alkali, drying, and distilling we separated 18 g of diethyl(p-ethoxyphenyl)phosphate (Table 2). When the reaction was repeated under the same conditions with the only difference that washing with 10% alkali was carried out before distillation, we obtained 21 g of the same phosphate. The reaction with other phosphites was carried out in an analogous way. In the reaction with trimethylphosphite a pure product was obtained without alkaline washing.

b) To 25 g of triethylphosphite was added dropwise with strong stirring a solution of 16.2 g of p-benzoquinone in moist benzene. We found a rise in temperature and to stop further heating the flask was cooled with ice water. An intense red color appeared where the drops of benzoquinone solution fell and disappeared at once when addition was stopped. During the reaction there was separation of hydroquinone which, reacting with p-benzoquinone, formed quinhydrone which settled to the bottom of the flask. The amount of quinhydrone formed decreased at the end of the reaction. When the reaction was complete, 2.7 g of quinhydrone had separated, m.p. 169-170°.

Found %: C 60.90, 61.20; H 4.72, 4.60. $C_{12}H_{10}O_4$. Calculated %: C 61.40; H 4.59.

The reaction mass stood until the next day at room temperature. As a result of vacuum distillation we obtained two substances: 1) 9 g of the crystalline complex of phosphate (IVa) with hydroquinone (Table 2, No. 5). Colorless crystals with m.p. 39-42° after repeated recrystallization from diisoamyl ether, b.p. 197-198° (12 mm). Soluble in alcohol, ether, benzene, chloroform and other organic solvents. Poorly soluble in diisoamyl ether. Decomposed by the action of alkaline water.

Found %: P 9.52; C 54.75; H 6.82. $C_{30}H_{44}O_{12}P_2$. Calculated %: P 9.42; C 54.71 H 6.69.

2) Seventeen g of product A. After freezing out the crystalline complex (at −20°, we isolated 7.5 g) and washing with alkaline water, we obtained 6 g of diethyl-(p-ethoxyphenyl)phosphate.

A crystalline complex identical with that described above was obtained by evaporation of an alcohol solution of hydroquinone and phosphate (IVa) in the ratio 1 : 2 and by the action of water on this solution. A sample of a mixture of the crystals obtained in all three cases gave no melting point depression.

c) To 6.5 g of benzoquinone dissolved in anhydrous alcohol was added 10 g of triethylphosphite. On addition of the phosphite, the solution became brownish-red. The reaction was carried out with cooling, so that the reaction temperature of the mixture did not rise above 30°. After the end of the reaction the color did not change. After removing the alcohol we vacuum distilled, and as a result isolated 3.5 g of triethylphosphate (b.p. 95-97° at 10 mm, $n^{20}D$ 1.4120) and 8 g of hydroquinone. When the hydroquinone was dissolved in water 0.5 g of insoluble crystals remained, with m.p. 42-44°. A sample mixed with complex (VI) gave no melting point depression.

d) To a benzene solution of 5.4 g of benzoquinone was added a benzene solution of 16.6 g of triethylphosphite and 3 g of glacial acetic acid. The reaction took place very violently and the color of the solution during the reaction was brownish-green. At the end of the reaction the solution was tea colored. After removal of the benzene we isolated by vacuum distillation 5.2 g of crystalline complex (VI) with m.p. 42°, which gave no depression of the melting point when mixed with forms of complex (VI) obtained earlier.

Besides the experiments described above we carried out experiments on running the reaction of triethylphosphite with benzoquinone under the same conditions as in the first experiment, but with ratios of reagents 2 : 1 and 1 : 2, and, under the same conditions as in the first experiment, but at temperatures not above 20°, and, on the contrary by adding the phosphite to a boiling benzene solution of quinone. In all cases the results obtained did not differ from each other.

Addition of Triphenylphosphite to p-Benzoquinone

To a benzene solution of 6.9 g of p-benzoquinone was added dropwise 20 g of triphenylphosphite. No heating occurred and the color of the solution did not change. The reaction mixture was heated 20 hr on the water bath at 80-85°. A yellowish precipitate appeared on the walls of the flask. The precipitate was separated and washed with benzene. Yield 5 g (18%). Yellow crystals which decomposed in air with evolution of phenol, keeping well in a vacuum and an atmosphere of nitrogen, melting with decomposition at 72-73°.

Found %: P 7.45, 7.69. $C_{12}H_{19}O_5P$. Calculated %: P 7.41.

The intermediate addition product of triphenylphosphite and p-benzoquinone was easily decomposed with evolution of phenol under the action of moisture, alcohol, or by heating. Attempts to distill the remaining liquid part of the reaction product were not successful; the reaction product decomposed with evolution of phenol.

Saponification of diethyl(p-ethoxyphenyl)phosphate. We used 5 g of phosphate and 20 ml of 18% hydrobromic acid. Saponification was carried out in a sealed tube at 140°. After eight hours the saponification was complete. After evaporation of the solvent and removal of excess hydrogen bromide, crystals precipitated which after purification by boiling with activated charcoal in alcohol solution melted at 170°. A sample mixed with hydroquinone gave no melting point depression. Yield 1.2 g.

Preparation of diethyl(p-ethoxyphenyl)phosphate. To an ether solution of 5 g of monoethyl ether of hydroquinone and 4 g of triethylamine was added dropwise 6.2 g of diethylchlorophosphate. Reaction took place at 35-40°. After four hours the reaction was considered complete. During the reaction 5.2 g (92%) of triethylamine hydrochloride formed. As a result of vacuum distillation we obtained 2 g (42.0%) of the diethyl ester of (p-ethoxyphenyl)-phosphoric acid.

B.p. 166-167° (4 mm), $n^{20}D$ 1.4830, $d^{20}D$ 1.1451.

Found %: P 11.22, 11.36. $C_{12}H_{19}O_5P$. Calculated %: P 11.31.

Addition of Triethylphosphite to 1,4-Naphthoquinone

To a benzene solution of 12 g of 1,4-naphthoquinone was added dropwise 12.5 g of triethylphosphite. After some time the temperature of the reaction mixture spontaneously rose to 38° and the solution became dark brown. On the next day the reaction product was fractionated. As a result we obtained 13.5 g (54.2%) of diethyl-4-ethoxy-naphthylphosphate.

B.p. 200-204° (2 mm), $n^{20}D$ 1.5480, d^{20}_0 1.1863.

Found %: P 9.41. $C_{16}H_{21}O_5P$. Calculated %: P 9.56.

In an analogous way we carried out the reactions of 1,4-naphthoquinones with the other phosphites.

SUMMARY

1. We have studied the reaction of trialkylphosphites with p-benzoquinone and 1,4-naphthoquinone. Addition of the trialkylphosphites to the quinones occurred in position 1,6- with formation of the corresponding phosphates. We have made some suggestions as to the course of the reaction mechanism.

2. We have studied the reaction of trialkylphosphites with p-quinones by the method of paramagnetic resonance and showed that free radicals are formed only in the reaction with chloroanil; unsubstituted quinones do not form free radicals in this reaction.

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SYNTHESIS OF ACETALS

OF SUBSTITUTED TETRAHYDROBENZALDEHYDE

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Continuing work on the synthesis of acetals of the tetrahydrobenzaldehyde series, which are of interest as intermediates in the synthesis of carotenoid compounds and analogs of Vitamin A, we prepared acetals with various substituents in the cyclohexane ring. The synthesis was carried out according to the scheme of [1].

$R = H, Cl, CH_3;$ $R' = CH_3, C_2H_5.$
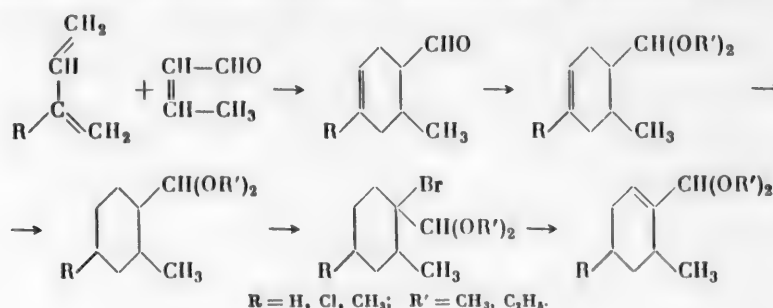
Butadiene (R = H), chloroprene (R = Cl), and isoprene (R = CH_3) were taken as the initial diene. The diene synthesis using chloroprene and crotonaldehyde gave a low yield ($\sim 7\%$) of the chlorine-substituted tetrahydrobenzaldehyde, unreported in the literature, and large quantities of a polymeric product. A series of experiments was conducted varying a) quantity of solvent (toluene), b) temperature and time of heating (100-200°, 1.5-12 hr), and c) stabilizers (hydroquinone, Neozone, copper turnings), but this was not successful in increasing the yield. By the action of orthoformic ester on the chloroaldehyde (I), its diethyl acetal (II) was prepared. The diene syntheses using butadiene and isoprene with crotonaldehyde were carried out at 180-200°, i.e., under conditions to form trans-2-methyl-Δ^4-tetrahydrobenzaldehyde [2, 3]. The dimethyl and diethyl acetals of 2-methyl-Δ^4-tetrahydrobenzaldehyde (III, IV) and of 2,4-dimethyl-Δ^4-tetrahydrobenzaldehyde (V, VI) were obtained with good yields on the action of methyl or ethyl alcohol respectively on the aldehydes in the presence of small quantities of hydrochloric acid.

In view of the difficult availability of the acetal of the chlorotetrahydrobenzaldehyde, no further work was carried out on it. The acetals of 2-methyl-Δ^4-tetrahydrobenzaldehyde and of 2,4-dimethyl-Δ^4-tetrahydrobenzaldehyde were hydrogenated on 5% Pd/BaSO$_4$ catalyst, giving good yields of the acetals of 2-methyl- and 2,4-dimethyl-hexahydrobenzaldehyde (VII-X).

Bromination of the acetals (VII-X) was carried out with an equimolar quantity of bromine. Since the bromination may be accompanied by replacement of one of the alkoxy groups by bromine, the reaction product was treated with the corresponding alcohol (methyl or ethyl). The resulting acetals of 1-bromo-2-methylhexahydrobenzaldehyde (XI, XII) and of 1-bromo-2,4-dimethylhexahydrobenaldehyde (XIII, XIV) were subjected further to dehydrobromination by the action of a tenfold excess of powdered potassium hydroxide. The dehydrobromination can go in two directions: with the formation of the acetals of 2-methyl-Δ^1-tetrahydrobenzaldehyde and 2,4-dimethyl-Δ^1-tetrahydrobenzaldehyde, or of the acetals of 2-methyl-Δ^6- and 2,4-dimethyl-Δ^6-tetrahydrobenzaldehyde.

It had been shown earlier that dehydrobromination of the 1-bromo-2-methylhexahydrobenzaldehyde itself by diethylaniline [4], the same as the dehydrobromination of other analogous bromaldehydes by diethylaniline or quinoline [5], leads only to Δ^1-tetrahydrobenzaldehydes. In order to determine the position of the double bond in the α,β-unsaturated acetals which were obtained (XV-XVIII), these were saponified to the aldehydes. On saponifiying

TABLE 1. Unsaturated Aldehydes

	Formula of aldehyde	λ_{max} mμ	ε_{max}	n^{20}_{D}	Literature reference
β-Methylsubstituted α,β-unsaturated aldehydes	$(CH_3)_2C{=}CH{-}CHO$	235	6700	1.4526	[7]
	(cyclohexene)—CHO	249	11600	1.4955	[8]
	(cyclohexene)—CHO	247	12400	1.5045	[3]
	(cyclohexene)—CHO	242, 251	11200, 11200	1.5091 (18°)	[4]
α,β-Unsaturated aldehydes without methyl groups in the β-position.	$\overset{H}{\underset{CH_3}{}}C{=}CH{-}CHO$	217	15650	1.4400	[7]
	(cyclohexene)—CHO	229	12100	1.4920	[4]
	(cyclohexene)—CHO	230	12200	1.4880	
	(cyclohexene)—CHO	230	13550	1.4791	

the dimethylacetal of the α,β-unsaturated 2-methyltetrahydrobenzaldehyde (XV), an aldehyde was obtained whose constants and melting point of the 2,4-dinitrophenylhydrazone agreed with those for 2-methyl-Δ^6-tetrahydrobenzaldehyde [6]. On oxidizing this aldehyde with atmospheric oxygen, 2-methyl-Δ^6-tetrahydrobenzoic acid was obtained.
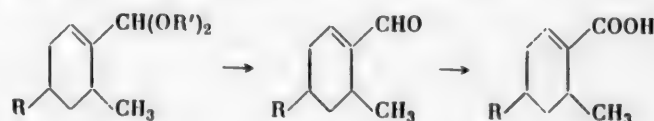
On saponifying the dimethyl and diethyl acetals of the α,β-unsaturated 2,4-dimethyltetrahydrobenzaldehyde (XVII, XVIII), an aldehyde was obtained with constants and melting point of the 2,4-dinitrophenylhydrazone differing significantly from those for 2,4-dimethyl-Δ^1-tetrahydrobenzaldehyde. On the basis of refractive index and UV absorption maximum (see Table 1), we have ascribed to it the structure 2,4-dimethyl-Δ^6-tetrahydrobenzaldehyde. On comparing the refractive indices and absorption maxima of α,β-unsaturated aldehydes with and without methyl groups in the β-position, it may be noted that for the β-methyl-substituted unsaturated aldehydes λ_{max} is shifted about 20 mμ toward the long-wave region in comparison with λ_{max} of unsaturated aldehydes without a methyl group in the β-position. The refractive index for β-methyl-substituted aldehydes is higher than for the unsubstituted by approximately 0.02 units (Table 1).

Consequently, the dehydrobromination of the acetals of 1-bromo-2-methyl- and 1-bromo-2,4-dimethylhexahydrobenzaldehydes goes contrary to the Saytzeff rule and to the rule of trans-elimination in the 1,6-position, in

TABLE 2.

Acetals of Substituted Δ⁴-Tetrahydrobenzaldehydes

No. of substance	R	R'	Boiling point (pressure in mm)	n^{20}_D	d^{20}_{20}	Yield (%)	M.p. of 2,4-dinitro-phenylhy-drazone	Found (%)		Formula	Calculated (%)	
								C	H		C	H
(III)	H	CH_3	58—60° (3)	1.4558	0.9571	82	160—161°	70.57, 70.36	10.96, 10.66	$C_{10}H_{18}O_2$	70.54	10.65
(IV)	H	C_2H_5	80 (2)	1.4508	0.9266	72	—	73.12, 73.07	11.29, 11.19	$C_{12}H_{22}O_2$	72.73	11.11
(V)	CH_3	CH_3	85—87 (9)	1.4581	0.9469	53	158—160	72.15, 72.29	10.88, 10.91	$C_{11}H_{20}O_2$	71.70	10.88
(VI)	CH_3	C_2H_5	80—81 (1.5)	1.4565	0.9135	81	—	73.70, 73.96	11.32, 11.28	$C_{13}H_{24}O_2$	73.53	11.39

TABLE 3

Acetals of Substituted Hexahydrobenzaldehydes

No. of substance	R	R'	Boiling point (pressure in mm)	n^{20}_D	d^{20}_{20}	Yield (%)	M.p. of 2,4-dinitro-phenylhy-drazone	Found (%)		Formula	Calculated (%)	
								C	H		C	H
(VII)	H	CH_3	59° (1.5)	1.4454	0.9276	85	150—151°	70.08, 70.16	11.52, 11.59	$C_{10}H_{20}O_2$	69.70	11.76
(VIII)	H	C_2H_5	70—72 (2)	1.4427	0.9048	90	—	71.63, 71.78	11.91, 12.10	$C_{12}H_{24}O_2$	71.94	12.07
(IX)	CH_3	CH_3	63—64 (22)	1.4442	0.9250	80	—	71.26, 71.29	11.92, 12.01	$C_{11}H_{22}O_2$	70.92	11.90
(X)	CH_3	C_2H_5	82 (2)	1.4468	0.8940	90	108—110	72.67, 72.58	12.21, 12.12	$C_{13}H_{26}O_2$	72.84	12.22

contrast to the dehydrobromination of the corresponding aldehydes, which leads to the formation of 1,2-unsaturated aldehydes. It must be noted that the dehydration of the cyanohydrin of 2-methylcyclohexanone also goes in the 1,6-position.

EXPERIMENTAL

Chloro-2-methyl-Δ^4-tetrahydrobenzaldehyde*(I). A solution of 20 g crotonaldehyde (b.p. 102-104°, n^{20}D 1.4390), 25 g chloroprene (b.p. 58-59.3°, n^{20}D 1.4605), 2 g hydroquinone, and 40 ml toluene was heated in a steel ampule 1.5 hr at 200°. The resulting product was steam distilled (41 g of rubberlike polymer remained in the distilling flask). The distillate, consisting of an aqueous and an organic layer, was separated and the aqueous layer was extracted with toluene. The toluene extracts, together with the organic layer, were dried with calcium chloride and vacuum distilled. The toluene was distilled off at 80 mm, and then the pressure was reduced to 2 mm. Obtained 3.5 g (7.5%) chloro-2-methyl-Δ^4-tetrahydrobenzaldehyde.

B.p. 68-70° (2 mm), n^{20}D 1.5121, d^{20}_{20} 1.1245.

Found %: C 61.16, 61.08; H 6.49, 6.59. $C_8H_{11}OCl$. Calculated %: C 60.57; H 6.93.

2,4-Dinitrophenylhydrazone, m.p. 183-185° (from alcohol).

Found %: N 16.65. $C_{14}H_{15}O_4N_4Cl$. Calculated %: N 16.54.

Diethyl acetal of chloro-2-methyl-Δ^4-tetrahydrobenzaldehyde (II). A solution of 9.9 g chloro-2-methyl-Δ^4-tetrahydrobenzaldehyde, 13.3 g orthoformic ester, and 1 mg p-toluenesulfonic acid in 50 ml anhydrous alcohol was kept at room temperature for two days. Then the solution was diluted with 90 ml ether, washed with 90 ml saturated sodium bicarbonate solution, and dried with potassium carbonate. Vacuum distillation gave 4.6 g (33.5%) of the diethyl acetal of chloro-2-methyl-Δ^4-tetrahydrobenzaldehyde.

B.p. 68-69° (0.25 mm), n^{20}D 1.4900, d^{20}_{20} 1.0724.

Found %: C 62.26, 61.94; H 8.50, 8.62. $C_{12}H_{21}O_2Cl$. Calculated %: C 61.91; H 9.04.

Diethyl acetal of 2,4-dimethyl-Δ^4-tetrahydrobenzaldehyde (VI). A mixture of 68 g 2,4-dimethyl-Δ^4-tetrahydrobenzaldehyde (b.p. 65-67° at 8 mm, n^{20}D 1.4691), 270 ml anhydrous alcohol, and 4 ml hydrochloric acid (d^{20}_4 1.18) was kept at room temperature for three days, after which it was poured into 250 ml water containing 10.5 g sodium carbonate. The liberated oil was separated off, and the aqueous layer was extracted with ether (400 ml). The ether extract, combined with the oil, was dried with potassium carbonate. After distilling off the ether, the residue was vacuum distilled. Obtained 23 g (34% of quantity taken) of the initial 2,4-dimethyl-Δ^4-tetrahydrobenzaldehyde with b.p. 68-75° (20 mm), n^{20}D 1.4655; also 55 g (81% on the aldehyde entering into the reaction) of the diethyl acetal of 2,4-dimethyl-Δ^4-tetrahydrobenzaldehyde (VI). Its constants are shown in Table 2.

There were obtained similarly the dimethyl acetal of 2,4-dimethyl-Δ^4-tetrahydrobenzaldehyde (V) and the dimethyl and diethyl acetals of 2-methyl-Δ^4-tetrahydrobenzaldehyde (III, IV), whose constants are shown in Table 2. The starting material for the preparation of the acetals (III) and (IV) was 2-methyl-Δ^4-tetrahydrobenzaldehyde with b.p. 65° at 15 mm and n^{20}D 1.4656.

Diethyl acetal of 2,4-dimethylhexahydrobenzaldehyde (X). A solution of 64.5 g of the diethyl acetal of 2,4-dimethyl-Δ^4-tetrahydrobenzaldehyde (VI) in 170 ml of anhydrous alcohol was agitated in a current of hydrogen in the presence of 2 g of 5% Pd/BaSO$_4$. After 16 hr 7.3 liters of hydrogen had been absorbed, which corresponds to the hydrogenation of one double bond. The catalyst was filtered off, the alcohol was distilled off, and the hydrogenated product was vacuum distilled. Obtained 59 g (90%) of the diethyl acetal of 2,4-dimethylhexahydrobenzaldehyde (X); its contants are shown in Table 3.

There were obtained similarly the dimethyl acetal of 2,4-dimethylhexahydrobenzaldehyde (IX) and the dimethyl and diethyl acetals of 2-methylhexahydrobenzaldehyde (VII, VIII). Their constants are shown in Table 3.

Diethylacetal of 1-bromo-2,4-dimethylhexahydrobenzaldehyde (XIV). To a solution of 38.5 g of the diethyl acetal of 2,4-dimethylhexahydrobenzaldehyde (X) in 400 ml of anhydrous chloroform, there was added dropwise a

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*Position of the chlorine (4 or 5) was not established.

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TABLE 4
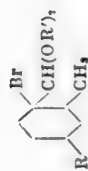
Acetals of Substituted 1-Bromohexahydrobenzaldehydes

No. of substance	R	R'	Boiling point (pressure in mm)	n^{20}_D	d^{20}_{20}	Yield (%)	Found (%) C	Found (%) H	Formula	Calculated (%) C	Calculated (%) H
(XI)	H	CH_3	100—102° (3)	1.4914	1.2752	70.5	48.20, 48.18	7.38, 7.48	$C_{10}H_{19}O_2Br$	47.82	7.62
(XII)	H	C_2H_5	106—107 (2)	1.4802	1.202	86	51.23, 51.41	8.03, 7.98	$C_{12}H_{23}O_2Br$	51.61	8.30
(XIII)	CH_3	CH_3	72—73 (0.2)	1.4585	1.2370	70	49.51, 49.59	7.67, 7.78	$C_{11}H_{21}O_2Br$	49.81	8.01
(XIV)	CH_3	C_2H_5	85—86 (0.1)	1.4788	1.1680	72	53.29, 53.06	8.35, 8.28	$C_{13}H_{25}O_2Br$	53.27	8.58

TABLE 5

Acetals of Substituted Δ^6-Tetrahydrobenzaldehydes

No. of substance	R	R'	Boiling point (pressure in mm)	n^{20}_D	d^{20}_{20}	Yield (%)	Found (%) C	Found (%) H	Formula	Calculated (%) C	Calculated (%) H
(XV)	H	CH_3	69—70° (2)	1.4598	0.9531	65	70.66, 70.71	10.34, 10.52	$C_{10}H_{18}O_2$	70.54	10.65
(XVI)	H	C_2H_5	68—70 (1)	1.4550	0.9219	90	73.14, 72.94	11.06, 10.80	$C_{12}H_{22}O_2$	72.73	11.11
(XVII)	CH_3	CH_3	56—58 (1.5)	1.4509	0.9983	70	71.28, 71.37	10.81, 11.10	$C_{11}H_{20}O_2$	71.63	10.94
(XVIII)	CH_3	C_2H_5	72—73 (1)	1.4551	0.9078	67	73.29, 73.60	11.45, 11.44	$C_{13}H_{24}O_2$	73.53	11.39

solution of 29.5 g bromine in 110 ml chloroform, with vigorous stirring, cooling to −7 to −10°, and illumination by a 300 w lamp. On completing the addition of bromine to the reaction mixture, there was poured in 150 ml anhydrous alcohol; the mixture was maintained 5 hr at room temperature and then treated with 100 ml 2 N sodium hydroxide (with cooling to +5°). The chloroform layer was separated, and the water layer was extracted three times with chloroform. The combined extracts were dried with potassium carbonate. After distilling off the chloroform over a small quantity of potassium carbonate, the residue was vacuum distilled. Obtained 4.5 g, 11.7% of the quantity taken, of the original diethyl acetal (X) with b.p. 65-72° (1.5 mm), $n^{20}D$ 1.4639; also 33.5 g of the diethyl acetal of 1-bromo-2,4-dimethylhexahydrobenzaldehyde (XIV), whose constants are shown in Table 4.

There were obtained similarly the dimethylacetal of 1-bromo-2,4-dimethylhexahydrobenzaldehyde (XIII) and the dimethyl and diethyl acetals of 1-bromo-2-methylhexahydrobenzaldehyde (XI, XII), whose constants are shown in Table 4.

Diethyl acetal of 2,4-dimethyl-Δ^6-tetrahydrobenzaldehyde (XVIII). A 29-g quantity of the diethyl acetal of 1-bromo-2,4-dimethylhexahydrobenzaldehyde (XIV) and 80 g of powdered potassium hydroxide were stirred at 130-135° 2.5 hr. After cooling, 60 ml water and 40 ml ether were added to the mixture. The ether and alkaline layers were separated, and the alkaline layer was extracted three times with ether (150 ml). The ether extracts were washed with water and dried with potassium carbonate. After distilling off the ether the product was vacuum distilled. Obtained 14 g of the diethyl acetal of 1-bromo-2,4-dimethyl-Δ^6-tetrahydrobenzaldehyde (XVIII); its constants are shown in Table 5. Resinous residue 4 g. From the diethyl acetal (XVIII) the 2,4-dinitrophenylhydrazone was obtained by the usual method, and after three recrystallizations from alcohol melted at 168-169°.

There were obtained similarly the dimethyl acetal of 2,4-dimethyl-Δ^6-tetrahydrobenzaldehyde (XVII) and the dimethyl and diethyl acetals of 2-methyl-Δ^6-tetrahydrobenzaldehyde (XV, XVI); their constants are shown in Table 5.

2-Methyl-Δ^6-tetrahydrobenzaldehyde (XIX). A solution consisting of 5 g dimethyl acetal of 2-methyl-Δ^6-tetrahydrobenzaldehyde (XV), 3.3 g phosphoric acid in 24 ml water, traces of hydroquinone, and 45 ml of dioxane was heated 1.5 hr on a steam bath, with stirring, in a nitrogen stream. The reaction mixture was treated with sodium bicarbonate solution (2.8 g in 50 ml of water), the layers were separated, and the water layer was extracted three times with ether. The organic layer, combined with the ether extracts, was dried with magnesium sulfate. On distillation there were obtained 2 g (50%) 2-methyl-Δ^6-tetrahydrobenzaldehyde (XIX).

B.p. 73° (13 mm), $n^{20}D$ 1.4880, d^{20}_{20} 0.9686, MR 36.88; calc. 36.49. λ_{max} 230 mμ, ε_{max} 12200.

2,4-Dinitrophenylhydrazone melted at 177.5-178° (from 1 : 2 mixture of CHCl$_3$ and C$_2$H$_5$OH), λ_{max} 385 mμ, ε_{max} 26200.

According to literature data [6]: b.p. 66-68° (10 mm), $n^{17}D$ 1.4898; 2,4-dinitrophenylhydrazone, m.p. 179°.

2-Methyl-Δ^6-tetrahydrobenzoic acid (XX). A one-gram quantity of 2-methyl-Δ^6-tetrahydrobenzaldehyde on standing for 4 days was oxidized by atmospheric oxygen to 2-methyl-Δ^6-tetrahydrobenzoic acid, which after three recrystallizations from aqueous 33% alcohol melted at 103.5-104° [6], λ_{max} 216.2 mμ, ε_{max} 8300.

Found %: C 68.25, H 8.49. C$_8$H$_{12}$O$_2$. Calculated %: C 68.57; H 8.57.

2,4-Dimethyl-Δ^6-tetrahydrobenzaldehyde (XXI). A mixture of 7 g of the diethyl acetal of 2,4-dimethyl-Δ^6-tetrahydrobenzaldehyde (XVIII), 70 ml of dioxane, 30 ml water, 5 g phosphoric acid, and 0.2 g hydroquinone was heated on a steam bath 1 hr 40 min, with stirring, in a nitrogen stream. After cooling the mixture was neutralized with saturated sodium bicarbonate solution (4.3 g in 70 ml water). The product was extracted with ether, and the ether extracts were dried with magnesium sulfate. On distillation there was obtained 4.1 g (90%), 2,4-dimethyl-Δ^6-tetrahydrobenzaldehyde (XXI).

B.p. 75° (9 mm), $n^{20}D$ 1.4791, d^{20}_{20} 0.9324, λ_{max} 230 mμ, ε_{max} 18550.

The 2,4-dinitrophenylhydrazone obtained from this compound melted at 168.5-169.5° (from alcohol), λ_{max} 380 mμ, ε_{max} 18650. A mixed sample with the 2,4-dinitrophenylhydrazone obtained from the diethyl acetal (XVIII) did not give any melting-point depression.

Found %: N 17.45, 17.36. C$_{15}$H$_{18}$O$_4$N$_4$. Calculated %: N 17.60.

2,4-Dimethyl-Δ^6-tetrahydrobenzaldehyde with the constants cited above was also obtained by saponifying the dimethyl acetal (XVII) under analogous conditions.

2,4-Dimethyl-Δ^1-tetrahydrobenzaldehyde, according to literature data [5], has b.p. 98-100° (14 mm), $n^{18}D$ 1.4958.

SUMMARY

1. The dimethyl and diethyl acetals of 2-methyl-Δ^6- and 2,4-dimethyl-Δ^6-tetrahydrobenzaldehyde have been prepared.

2. Dehydrobromination of the acetals of 1-bromo-2-methyl-substituted hexahydrobenzaldehydes goes at the 1,6-position, but not at the 1,2-, as is observed in dehydrobromination of the aldehydes themselves.

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CONDENSED POLYMETHYLENE DERIVATIVES
OF HETEROCYCLES ON THE BASIS OF LACTAMS

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Almost no study has been given to 8,9-disubstituted β-purines up to the present time. In one of the studies [1] in the course of an investigation of β-diethylaminoalkyl derivatives of pyrimidine as potential antimalarial agents, three compounds were synthesized which are 8-methyl-9-diethylaminoalkyl derivatives of β-purine. In another study [2], in connection with a search for antimetabolites of natural purines, 6-mercapto-8,9-dimethylpurine was synthesized. Out of a number of compounds with a tricyclic system containing the purine skeleton, only a few compounds which are heterocyclic derivatives of purine have been reported [3-6].

The great interest aroused by β-purine derivatives (analogs of purines that enter into the composition of nucleic acids) induced us to make use of the capacity of O-methylcaprolactim to be converted readily into pentamethylene derivatives of both five- and six-membered heterocycles (which we described in previous communications [7-9]) for the synthesis of 8,9-pentamethylene derivatives of purine (I).

(I)
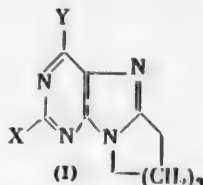
In resolving this problem we investigated two variants. In the first variant it was proposed to synthesize the purine derivatives (I) starting with pyrimidines. For this purpose, attempts were made to condense O-methylcaprolactim with uramil (IIa) and with 1,3-dimethyl-4,5-diaminouracil (IIb).

(IIa) R = H, X = OH ;   (IIb) R = CH₃ , X = NH₂ .
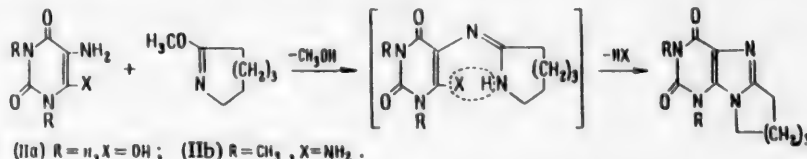
However, in a series of experiments conducted under various conditions this reaction did not give positive results, evidently because of the insufficiently basic properties of the 5-aminouracils.

In the second variant we intended to synthesize the amide of 1,2-pentamethylene-5-aminoimidazole-4-carboxylic acid (III) by the interaction of O-methylcaprolactim with α-amino-α-cyanacetamide and then to utilize (III) in synthesizing a purine derivative (I), according to the scheme:

H_2N-CO

CH—NH$_2$ + H$_3$CO—

NC

N (CH$_2$)$_3$

$\xrightarrow{CH_3OH}$

$\left[\begin{array}{c} H_2N-CO \\ CH \\ NC \quad HN \quad (CH_2)_3 \end{array} \right]^-$

(IV)

NH$_2$

H$_2$NCO—C

CN N (CH$_2$)$_3$

(V)

H_2N-CO

H_2N-C

C — N

N

—(CH$_2$)$_3$

(III)

(I)
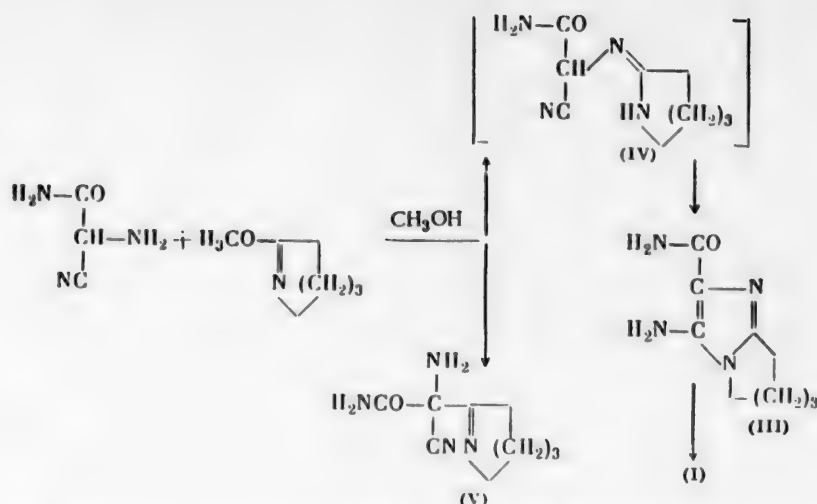
In carrying out such a condensation we took account of the ability of O-methylcaprolactim to react with compounds having an active CH_2 group [10], forming a new $-\overset{|}{C}-\overset{|}{C}-$ bond. [For the given case such a condensation product may be represented by Formula (V).] In addition, since intramolecular cyclizations involving $\,$NH and CN-groups occur as a rule in the presence of alkaline agents and at increased temperature, it is not ruled out that in the given case the formation of (IV) may be a stage in the normal course of the process. On the basis of these considerations, the structure of the compound with m.p. 272-274° which we obtained in the condensation of O-methylcaprolactim with α-amino-α-cyanacetamide might be that of one of the three isomeric compounds (III-V).

Absorption bands were detected in the IR spectrum which are characteristic for NH_2 and H_2NCO groups, and the CN absorption band was absent; moreover, this substance was diazotized normally, and its diazonium salt was condensed with α-naphthol, giving the violet-red color which is characteristic for similar imidazoles.

These data showed that the condensation product from O-methylcaprolactim and α-amino-α-cyanacetamide has the structure (III). For additional proof of structure of Compound (III), the hydrochloride and the base (III) were obtained by a countersynthesis from O-methylcaprolactim and aminomalonamidamidine dihydrochloride [11] (VI); the products proved to be fully identical with the hydrochloride and base(III) synthesized by the first method.

H_2N-CO

CH-NH$_2$ · 2HCl + H$_3$CO—

HN=C-NH$_2$

N (CH$_2$)$_3$

(VI)

$\longrightarrow$

$\left[\begin{array}{c} H_2N-CO \\ CH \quad N \\ HN=C \; (NH_2 \; H_2N) \; (CH_2)_3 \\ \cdot 2HCl \end{array} \right]$

$\rightarrow$ (III)
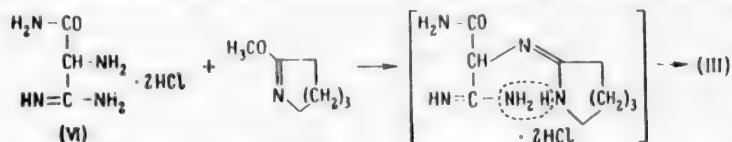
The structure of Compound (III) was demonstrated conclusively by its entire series of conversions of various 8,9-pentamethylenepurines, as is evident from the following scheme:

OH

(III) $\xrightarrow{HC(OC_2H_5)_3}$

N

N

N

—(CH$_2$)$_3$

(VII)

SH

$\xrightarrow{P_2S_5}$

N

N

N

—(CH$_2$)$_3$

(VIII)

$\xrightarrow{Ni}$

N

N

N

—(CH$_2$)$_3$

(IX)

$\downarrow$ POCl$_3$

$\downarrow$ (CH$_3$)$_2$SO$_4$

NRR'

N

N

N

—(CH$_2$)$_3$

(XII)

$\xleftarrow{HNRR'}$

Cl

N

N

N

—(CH$_2$)$_3$

(XI)

$\xrightarrow{H_2NC(S)NH_2}$

SCH$_3$

N

N

N

—(CH$_2$)$_3$

(X)
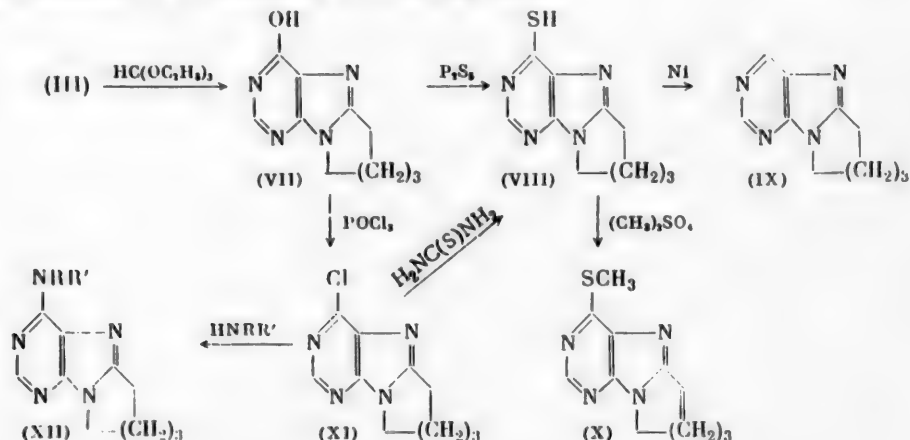
$$
\text{(XII)} \quad
\begin{array}{ll}
\textbf{a} & R = R' = H; \\
\textbf{b} & R = R' = CH_3; \\
\textbf{c} & R = H, \ R' = CH_2C_6H_5; \\
\textbf{d} & R = H, \ R' = CH_2 \\
\textbf{e} & R = H, \ R' = CH_2CH_2OH; \\
\textbf{f} & R = R' = CH_2CH_2OH.
\end{array}
$$

The UV-spectra of Compounds (VII) and (VIII) were found to coincide with the spectra of hypoxanthine and 6-mercaptopurine. It should be noted that the substance (III), like the amide of 1-methyl-5-aminoimidazole-4-carboxylic acid [12], does not form 8,9-pentamethylenexanthine with $CO(OC_2H_5)_2$ and urea. The fusion of the substance (III) with thiourea also proceeds unusually. In this reaction, instead of the expected 2-mercapto-6-hydroxy-8,9-pentamethylenepurine (XIII), there was formed 8,9-pentamethyleneguanine (XIV), the UV spectrum of which proved to be similar to that of guanine.
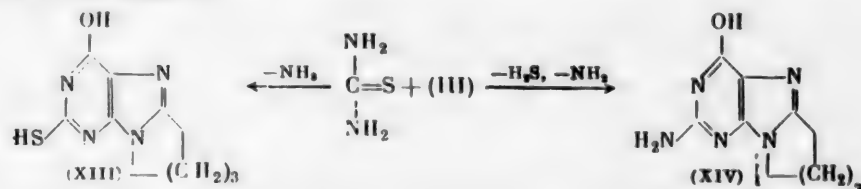
The well-known antitumor activity of certain bis(β-chloroethyl)amines led us to synthesize for biological investigation 6-bis(β-chloroethyl)amino-8,9-pentamethylenepurine. A study of the literature showed that in the case of a simple purine this reaction proceeds anomalously, forming a quaternary salt. The structure (XVa) and (XVb) has been proposed for this salt [13].
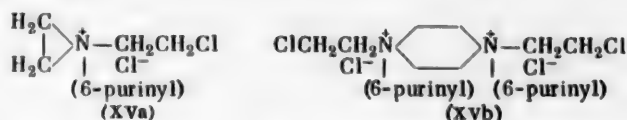
In our case, on heating Compound (XIIf) with thionyl chloride, Compound (XVI) was obtained, also containing both ionic and covalent chlorine, difficultly soluble in most organic solvents, and readily soluble in water. Of the three possible structures for (XVI) the most probable is the structure (XVIa).
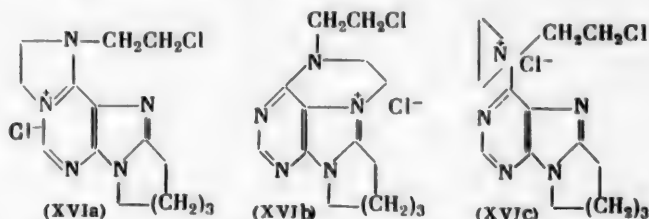
An indication in favor of structure (XVIa) is the ability of β-chloroethylamine derivatives of pyrimidine— even with the presence of an NH_2 group in position 5— to be cyclized readily into imidazolinopyrimidines (XVII) [14].
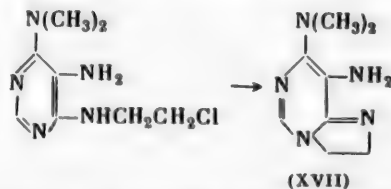
In confirmation of the structure (XVIa) we succeeded in accomplishing a similar type of cyclization by the action of thionyl chloride on Compound (XIIe); in all probability this resulted in the synthesis of the pentamethylene derivative of a new heterocycle, 8,9-pentamethylene-1,6-dihydropurino-[1,6-1',2']-imidazoline (XVIII), the UV-spectrum of which proved to be similar to that of (XVIa).

$$\text{(XIIe)} \rightarrow \text{(XVIII)}$$
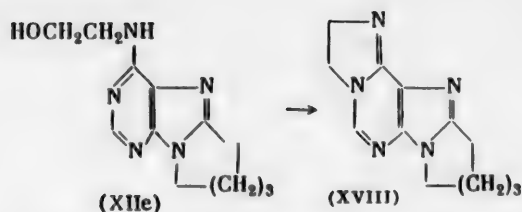
The reaction which we discovered, the formation of pentamethylene derivatives of heterocycles, bears a general character and affords the opportunity of preparing trimethylene and other polymethylene heterocycles, which will be discussed in a future communication.

EXPERIMENTAL

Amide of 1,2-pentamethylene-5-aminoimidazole-4-carboxylic acid (III). 1) Condensation of α-amino-α-cyanacetamide with O-methylcaprolactim in ethyl Cellosolve   A mixture of 5 g α-amino-α-cyanacetamide [15] and 20 ml O-methylcaprolactim was heated 1 hr in 20 ml ethyl Cellosolve at 95-100°. In the process of heating there was first formed a solution, then a precipitate, which on cooling was filtered off, washed with 15 ml alcohol, and dried. Obtained 5.2 g cream-colored substance with m.p. 269-272° (decomp. with gas evolution). The mother liquor on standing for several days gave a precipitate of an additional 0.8 g of material with m.p. 270-272° (decomp.). Total yield of amide of 1,2-pentamethylene-5-aminoimidazole-4-carboxylic acid 6 g (61.22%).

The substance was difficultly soluble in most organic solvents, crystallized from ethyl Cellosolve (1 : 20) and dimethyl formamide (1 : 20); difficultly soluble in alkalies, readily soluble in dilute acids; on diazotization and subsequent addition of alkaline α-naphthol solution it gave a purple coloration. For analysis the substance was cryatallized from water 1 : 80 (prisms), m.p. 272-274° (decomp.).

Found %: C 55.67; H 7.46; N 28.64. $C_9H_{14}ON_4$. Calculated %: C 55.67; H 7.21; N 28.86.

2) Condensation of α-amino-α-cyanacetamide with O-methylcaprolactim in alcoholic hydrogen chloride solution. To a suspension of 9.9 g α-amino-α-cyanacetamide in 25 ml of anhydrous alcohol at −3 to −8° there was added slowly (dropwise) first 20 ml of 21% HCl− alcohol solution, so that the temperature did not exceed 0°, then 12.7 g O-methylcaprolactim. The reaction mixture stood overnight. With subsequent occasional stirring of the mixture the solution formed a precipitate. The mixture was boiled (with stirring) 1 hr and filtered, obtaining 6.9 g (30%) of the hydrochloride of the amide of 1,2-pentamethylene-5-aminoimidazole-4-carboxylic acid. For analysis it was crystallized first from alcohol 1 : 15, then from methanol 1 : 10 (long prisms), m.p. 257-259° (decomp.).

Found %: N 24.48; Cl 15.32. $C_9H_{14}ON_4 \cdot HCl$. Calculated %: N 24.30; Cl 15.40.

After recovering the 6.9 g of the hydrochloride, the mother liquor was treated with a 5% solution of picric acid in alcohol, obtaining 13.6 g (32%) of the yellow picrate of the amide of 1,2-pentamethylene-5-aminoimidazole-4-carboxylic acid, with m.p. 231-234° (decomp.).

Found %: C 42.38; H 4.01; H 23.21. $C_9H_{14}ON_4$ $HOC_6H_2(NO_2)_3$. Calculated %: C 42.55; H 4.01; N 23.16.

Conversion of the picrate to the hydrochloride of the amide of 1,2-pentamethylene-5-aminoimidazole-4-carboxylic acid was accomplished as follows: Into a chilled (ice−salt) suspension of 10 g of the picrate in 30 ml of anhydrous acetone, hydrogen chloride was passed until the yellow color disappeared; the sediment was filtered off and washed with 5 ml anhydrous acetone, obtaining 5.2 g (95.6%) of the hydrochloride of the amide of 1,2-pentamethylene-5-aminoimidazole-4-carboxylic acid, m.p. 253-256° (decomp.).

In titrating 0.1064 g of the hydrochloride in 10 ml water to phenolphthalein endpoint, 4.6 ml of 0.1 N NaOH was required.

Found %: M 231. $C_9H_{14}ON_4$. Calculated M 230.5.

By the end of the titration, crystals of the base (amide of 1,2-pentamethylene-5-aminoimidazole-4-carboxylic acid) had crystallized, m.p. 271-274° (decomp.).

3) Condensation of O-methylcaprolactim with α-aminomalonamidamidine dihydrochloride. To a suspension of 7.6 g aminomalonamidamidine dihydrochloride in 30 ml anhydrous alcohol, 10 ml O-methylcaprolactim was added dropwise over 20 min, thereby warming the mixture to 25°. The mixture was boiled 3 hr, cooled, and filtered, obtaining 4.45 g (59.89%) of the amide of 1,2-pentamethylene-5-aminoimidazole-4-carboxylic acid, m.p. 263-265° On heating the amide in HCl— methanol solution, the hydrochloride was obtained with m.p. 257-259° (decomp.), which did not give any melting-point depression in a mixed sample with the hydrochloride prepared by method "2."

6-Hydroxy-8,9-pentamethylenepurine (VII). A mixture of 8 g of the amide of 1,2-pentamethylene-5-amino-imidazole-4-carboxylic acid, 75 ml orthoformic ester, and 125 ml acetic anhydride was boiled 3.5 hr. In the process of heating the boiling point decreased from 117 to 105°; the solution which was formed was vacuum-distilled to dryness. A 150 ml quantity of 50% methanol was added and the mixture heated 4 hr; the crystals which precipitated were filtered off and washed first with water and then with alcohol. Obtained 7.8 g (92.74%) 6-hydroxy-8,9-penta-methylenepurine, m.p. 307-310° (decomp.); after crystallization from water 1 : 100 (prisms), m.p. 308-311°(decomp.). The substance was difficultly soluble in most organic solvents and readily soluble in dilute acids or alkalis and in ammonia solution; on dissolving in sodium carbonate solution CO_2 was evolved.

λ_{max} 250 mμ, log K 4.153 in 0.1 N HCl.

Found %: C 58.78; H 5.7; N 27.12. $C_{10}H_{12}ON_4$. Calculated %: C 58.82; H 5.88; N 27.45.

6-Chloro-8,9-pentamethylenepurine (XI). A mixture of 13.6 g 6-hydroxy-8,9-pentamethylenepurine, 400 ml phosphoryl chloride, and 35 ml dimethylaniline was boiled 3 hr, the solution (which darkened) was vacuum-distilled to dryness, and on cooling, 30 g of icc was added in portions to the residue; this resulted in the formation of a precipitate, which was filtered off. Yield 5.4 g, m.p. 140-142°. Extraction of the mother liquor with chloroform gave an additional 6.6 g of the substance with m.p. 139-141°. Total yield of 6-chloro-8,9-pentamethylenepurine 12 g (80.9%), m.p. 141-143° (from water).

The substance had good solubility in chloroform, alcohol, acetone, benzene, and ethyl acetate, was difficultly soluble in ether, and was insoluble in alkalis.

Found %: N 25.08; Cl 15.96. $C_{10}H_{11}N_4Cl$. Calculated %: N 25.16; Cl 15.95.

6-Mercapto-8,9-pentamethylenepurine (VIII). 1) From 6-hydroxy-8,9-pentamethylenepurine. A mixture of 45 g 6-hydroxy-8,9-pentamethylenepurine, 135 g P_2S_5, and 1800 ml anhydrous pyridine was boiled (with stirring) 4 hr. The reaction mixture was vacuum-distilled to dryness; the residue was boiled 1.5 hr with 1500 ml water, cooled, and filtered; obtained 52 g of a dark red substance, which on crystallization from 75% aqueous dimethyl formamide 1 : 40 gave 44.3 g (91.28%) 6-mercapto-8,9-pentamethylenepurine, m.p. 290-292° (decomp.). The substance was difficultly soluble in most organic solvents, soluble in dilute alkalis.

2) From 6-chloro-8,9-pentamethylenepurine. A suspension of 0.4 g 6-chloro-8,9-pentamethylenepurine and 0.15 g thiourea in 10 ml alcohol was boiled 1 hr 15 min. A solution was formed on heating from which a sediment again precipitated. After cooling the mixture, the precipitate was filtered off, washed with alcohol, and dried; weight 0.38 g (96.2%), m.p. 290-292° (decomp.); a mixed sample with 6-mercapto-8,9-pentamethylenepurine prepared by method "1" showed no melting-point depression.

Found %: N 25.18; S 14.64. $C_{10}H_{12}N_4S$. Calculated %: N 25.45; S 14.54.

8,9-Pentamethylenepurine (IX). To 4.5 g 6-mercapto-8,9-pentamethylenepurine in 600 ml hot water, 15g of moist Raney nickel catalyst was added, and the mixture was boiled for 4 hr. At the end of the reaction the mixture was filtered, the mother liquor was vacuum-distilled to dryness, the residue was dissolved in 150 ml of chloroform, the solution was dried with calcined Na_2SO_4, the chloroform was distilled off, 10 ml n-hexane was added to the residue, and the mixture was filtered; obtained 3.1 g (80.72%) 8,9-pentamethylenepurine, m.p. 98-100°. The substance was readily soluble in water with a weakly alkaline reaction, readily soluble in alcohol, chloroform, benzene, acetone, and ethyl acetate, and difficultly soluble in ether and n-hexane. For analysis the substance was crystallized from a mixture of ether and ethyl acetate.

Found %: C 63.70; H 6.47; N 29.43. $C_{10}H_{12}N_4$. Calculated %: C 63.82; H 6.38; N 29.78.

Picrate of 8,9-pentamethylenepurine, m.p. 166-169°.

Found %: N 23.30. $C_{10}H_{12}N_4 \cdot HOC_6H_2(NO_2)_3$. Calculated %: N 23.50.

6-Methylmercapto-8,9-pentamethylenepurine (X). To 8.8 g of 6-mercapto-8,9-pentamethylenepurine in 45 ml 1 N NaOH, 4.9 ml dimethyl sulfate was added dropwise at 20° over 40 min. The mixture was thereby warmed to 32°. After holding for 1.5 hr with stirring, the reaction mixture was filtered; obtained 8.2 g (87.6%) 6-methyl-mercapto-8,9-pentamethylenepurine, m.p. 134.5-136.5°; after crystallization from ethyl acetate 1 : 9 (plates), m.p. 139-141°. The substance was difficultly soluble in water and in ether, readily soluble in chloroform, benzene, acetone, and methanol.

Found %: C 56.35; H 5.74; S 13.55. $C_{11}H_{14}N_4S$. Calculated %: C 56.41; H 5.98; S 13.67.

2-Amino-6-hydroxy-8,9-pentamethylenepurine (XIV). A mixture of 14 g of the amide of 1,2-pentamethylene-5-aminoimidazole-4-carboxylic acid and 30 g of thiourea was heated 2.5 hr in a Woods metal bath (bath tempera-ture 230-250°). On cooling, the dark melt was dissolved with heating in 250 ml 2 N NaOH, the hot solution was acidified with acetic acid to pH ~ 7, and the resulting precipitate was filtered off and washed with alcohol; obtained 14.5 g of a substance which did not melt up to 360°.

The 2-amino-6-hydroxy-8,9-pentamethylenepurine was readily soluble in acids and alkalis, and difficultly soluble in most organic solvents; for analysis it was crystallized from 40% aqueous dimethyl formamide (prisms).

λ_{max} 254 mμ, log K 4.136, deflection 278 mμ, log K 3.9786 in 0.1 N HCl.

Found %: C 54.48; H 6.03; N 31.69. $C_{10}H_{13}ON_5$. Calculated %: C 54.79; H 5.93; N 31.96.

6-Amino-8,9-pentamethylenepurine (XIIa). A 3-g quantity of 6-chloro-8,9-pentamethylenepurine was heated (bath temperature 160-170°) 6 hr with 50 ml 18% NH$_3$ solution in alcohol in a 100-ml autoclave; the cooled mixture was filtered, obtaining 2.3 g of a substance with m.p. 222-225°. An additional 0.6 g of the substance with m.p. 223-225° was obtained by concentrating the alcoholic mother liquor. On crystallizing the 2.9 g of the substance from water, obtained 2.55 g (93.4%) 6-amino-8,9-pentamethylenepurine, m.p. 226.5-228.5°. It was readily soluble in methanol, difficultly soluble in ether, benzene, ethyl acetate, and acetone, and soluble in dilute acids and alkalis.

Found %: C 59.56; H 6.53; N 34.19, 34.77. $C_{10}H_{13}N_5$. Calculated %: C 59.11; H 6.40; N 34.48.

6-Dimethylamino-8,9-pentamethylenepurine (XIIb). A mixture of 1.5 g 6-chloro-8,9-pentamethylenepurine and 40 ml 18% solution of dimethylamine in anhydrous methanol was heated (bath temperature 102-108°) in a sealed ampule for 1 hr. The resulting solution was vacuum-distilled, the residue was suspended in 7 ml cold water, concentrated NH$_4$OH was added to pH 8, and the mixture was filtered. Obtained 1.4 g (90.3%) 6-dimethylamino-8,9-pentamethyl-enepurine, m.p. 142-144°; for analysis it was crystallized from ether 1 : 60 (prisms). It was readily soluble in most solvents and in dilute acids.

Found %: C 62.60; H 7.07; N 30.38. $C_{12}H_{17}N_5$. Calculated %: C 62.34; H 7.35; N 30.30.

6-Benzylamino-8,9-pentamethylenepurine (XIIc). A mixture of 1.6 g 6-chloro-8,9-pentamethylenepurine and 9 ml benzylamine in 15 ml ethyl Cellosolve (b.p. 134-138°) was boiled 2 hr; the reaction mixture was vacuum distilled to dryness, the residue was suspended in water, and saturated sodium carbonate solution was added to pH 8.0; the mixture was filtered, obtaining 1.6 g (74%) 6-benzylamino-8,9-pentamethylenepurine with m.p. 153-155° (from 50% methanol). It was well soluble in chloroform, soluble with heating in ethyl acetate, acetone, and alcohol, dif-ficultly soluble in water and ether, well soluble in dilute acids.

Found %: C 69.68; H 6.95; N 23.63. $C_{17}H_{19}N_5$. Calculated %: C 69.62; H 6.48; N 23.88.

6-Furfurylamino-8,9-pentamethylenepurine (XIId). A mixture of 2 g 6-chloro-8,9-pentamethylenepurine and 4 ml furfurylamine [16] was boiled 2 hr in 20 ml ethyl Cellosolve. On completing the reaction, a sample of the mix-ture was rubbed on a watch glass, and the crystals which were formed were added to the hot reaction mixture. On cooling, the precipitated crystals were filtered off and washed with alcohol, obtaining 1.45 g of a substance with m.p. 168-170°. Concentrating the mother liquor gave a dark residue from which after crystallization from 50% of alcohol an additional 0.85 g was obtained with m.p. 167-170°. Total yield of 6-furfurylamino-8,9-pentamethylene-purine 2.3 g (90.5%). It was readily soluble in chloroform and in dilute acids, soluble with heating in ethyl acetate and alcohol, and difficultly soluble in water, acetone, and ether.

Found %: C 63.68; H 6.14; N 24.90. $C_{15}H_{17}ON_5$. Calculated %: C 63.60; H 6.00; N 24.73.

6-[bis(β-Hydroxyethyl)]amino-8,9-pentamethylenepurine (XIIf). A mixture of 2.5 g 6-chloro-8,9-penta-methylenepurine, 5 g diethanolamine, and 25 ml of ethyl Cellosolve was boiled 2 hr. The resulting solution was vacuum-distilled, and the residue was triturated with 40 ml of water and filtered, obtaining 2.65 g of a substance with m.p. 176-178°. Extraction of the mother liquor with chloroform gave an additional 0.25 g of the substance with m.p. 175-177°. Total yield of 6-[bis(β-hydroxyethyl)]amino-8,9-pentamethylenepurine 2.9 g (89.2%), m.p. 177-179° (from water). The substance was readily soluble in chloroform, methanol, and dilute acids, and more dif-ficultly soluble in water, acetone, benzene, and ethyl acetate.

Found %: C 57.48; H 7.41; N 23.89, 24.33. $C_{14}H_{21}O_2N_5$. Calculated %: C 57.73; H 7.21; N 24.05.

Inner quaternary salt of 6-[bis(β-chloroethyl)]amino-8,9-pentamethylenepurine (XVI). To a solution of 2.65 g 6-[bis(β-hydroxyethyl)]amino-8,9-pentamethylenepurine in 40 ml of dry chloroform, with ice water cooling, a solu-tion of 10 ml $SOCl_2$ in 10 ml of dry chloroform was added dropwise; the reaction mixture was boiled 3.5 hr and vac-uum-distilled. The residue, a dark resinous mass, was dissolved in 20 ml ice water, and a saturated sodium carbonate solution was added dropwise to pH 7.5-7.9. The resulting solution was vacuum-distilled to dryness, and the residue was extracted with boiling anhydrous alcohol; obtained 2.6 g (80%) of a substance with m.p. 205-207°. The substance was difficultly soluble in most organic solvents and readily soluble in water, alcohol, and acetic acid; for analysis 2.5 g was crystallized from a mixture of 20 ml acetone and 4 ml of anhydrous alcohol (needles).

M.p. 208-210°, λ_{max} 271 mμ (log K 4.201), λ_{min} 242 mμ (log K 3.367).

Found %: N 21.30; $Cl_{tot.}$ 21.80; Cl_{ion} 10.85. $C_{14}H_{19}N_5Cl_2$. Calculated %: N 21.34; $Cl_{tot.}$ 21.65; Cl_{ion} 10.82.

6-(β-Hydroxyethyl)amino-8,9-pentamethylenepurine (XIIe). A mixture of 2 g 6-chloro-8,9-pentamethylene-purine, 2 g β-aminoethanol, and 20 ml of ethyl Cellosolve was boiled 2 hr; the resulting solution was vacuum-dis-tilled and the residue triturated with 3 ml cold water and filtered, obtaining 1.45 g of a substance with m.p. 120-122°. Chloroform extraction of the mother liquor gave an additional 0.6 g of the substance with m.p. 120-124°. Total yield of 6-(β-hydroxyethyl)amino-8,9-pentamethylenepurine 2.05 g (92.3%); after crystallization from a small quan-tity of ethyl acetate (long prisms), m.p. 127-128.5°. The substance was fairly readily soluble in most organic solvents and in water with a weakly alkaline reaction.

Found %: C 58.35; H 6.82; N 28.12. $C_{12}H_{17}ON_5$. Calculated %: C 58.29; H 6.88; N 28.34.

8,9-Pentamethylene-1,6-dihydropurino[1,6-1',2']imidazoline (XVIII). To a solution of 1.7 g 6-(β-hydroxy-ethyl)-amino-8,9-pentamethylenepurine in 30 ml of dry chloroform, 5 ml of thionyl chloride was added dropwise with ice-cooling. The mixture was heated to boiling, thereby forming a precipitate which did not dissolve in 3.5 hr of subsequent boiling; on cooling, the precipitate was filtered off and washed with dry chloroform, obtaining 2 g of the hemihydrate of 8,9-pentamethylene-1,6-dihydropurino[1,6-1',2']imidazoline dihydrochloride, m.p. 310-313° (decomp.). For analysis 0.6 g of the substance was crystallized from a mixture of 10 ml acetone and 20 ml alcohol.

M.p. 312-314° (decomp.), λ_{max} 266 mμ (log K 4.174), λ_{min} 238 mμ (log K 3.379).

Weight loss 0.0035 g on drying a 0.1248 g sample (~100°, 15 mm).

Found %: N 22.49; Cl 22.59. $C_{12}H_{15}N_5 \cdot 2HCl \cdot 0.5 H_2O$. Calculated %: N 22.50; Cl 22.82.

Treatment of a solution of 1.25 g of the hemihydrate of 8,9-pentamethylene-1,6-dihydropurino[1,6-1',2']imi-dazoline dihydrochloride in 10 ml of water, adding 40% KOH up to pH 9.0, gave a precipitate of 0.95 g of the tetra-hydrate of 8,9-pentamethylene-1,6-dihydropurino[1,6-1',2']imidazoline, m.p. 97-100° (from water 1 : 10). The substance was soluble with heating in benzene, acetone, ethyl acetate, and chloroform, and readily soluble in meth-anol.

Weight loss 0.0289 g on drying a 0.1307 g sample (~ 100°, 15 mm).

Found %: N 23.17, 23.57. $C_{12}H_{15}N_5 \cdot 4H_2O$. Calculated %: N 23.22.

On treating an alcoholic solution of the base with an alcoholic HCl solution, the dihydrochloride was precip-itated with m.p. 312-314° (decomp.); it gave no melting-point depression in a mixed sample with the dihydrochlo-ride obtained above.

SUMMARY

1. O-Methylcaprolactim readily enters into condensation with α-amino-α-cyanacetamide and also with aminomalonamidamidine, forming the amide of 1,2-pentamethylene-5-aminoimidazole-4-carboxylic acid, which opens a new route for preparing cyclically substituted imidazoles.

2. From the amide of 1,2-pentamethylene-5-aminoimidazole-4-carboxylic acid it was found possible to proceed to the synthesis of a number of substituted 8,9-pentamethylenepurines, representatives of a new class of 8,9-polymethylenepurines.

3. On melting the amide of 1,2-pentamethylene-5-aminoimidazole-4-carboxylic acid with thiourea, the latter reacts the NH_2 and SH groups, forming 8,9-pentamethyleneguanine.

4. On treating 6-[bis(β-hydroxyethyl)]amino-8,9-pentamethylenepurine with thionyl chloride, an internal cyclization occurs at the expense of one β-chloroethyl group, forming a cyclic quaternary salt. A similar cyclization takes place on heating 6-(β-hydroxyethyl)amino-8,9-pentamethylenepurine with thionyl chloride, in all probability forming the pentamethylene derivative of a new heterocycle, 8,9-pentamethylene-1,6-dihydropurino[1,6-1',2']imidazoline.

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THE CHLORINATION OF FLUORENE

WITH N,N-DICHLOROBENZENESULFONAMIDE

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The action of elementary chlorine on fluorene has been studied in extremely great detail, the primary products of chlorination (2-chlorofluorene and 2,7-dichlorofluorene) being obtained in small yields. The chlorination of fluorene by other halogenating agents has been discussed in the literature to a very slight extent, but information on the action of N,N-dichlorobenzenesulfonamide on fluorene are lacking.

In the chlorination of fluorene with chlorine in chloroform solution, a mixture of 2-chloro- and 2,7-dichlorofluorenes is always obtained with one or other of these products predominating according to the reaction conditions; the isolation of a reaction product in pure form is extremely difficult [1, 2]. The chlorination of fluorene in solution in carbon tetrachloride leads, when the process is prolonged, to a formation of a mixture of polychloro derivatives from which only the hexachloride can be isolated as a separate individual [3]. A mixture of polychloro derivatives with a mean content of chlorine of about 50% can be obtained by the action of chlorine on fluorene [4]. The production of 2-chlorofluorene by a short treatment of fluorene with sulfuryl chloride has also been reported [5].

The photochemical reaction between fluorene and carbon tetrachloride in the presence of trimethylbenzyl-ammonium hydroxide leads to the formation of 9,9-dichlorofluorene, which is usually obtained by the treatment of fluorene with phosphorus pentachloride. As far as concerns N-halogenoamides and fluorene, in particular, the action on it of 1,3-dibromohydantoin and 3-bromo-5,5-dimethylhydantoin in carbon tetrachloride yields 9-bromofluorene [6-10]. Only photochemical processes lead to the replacement of the hydrogen in position 9; in other cases the halogen replaces hydrogen in the nucleus.

N,N-Dichlorobenzenesulfonamide is an extremely mild halogenating agent, permitting the smooth halogenation of many organic compounds. It is being used successfully in a number of cases for chlorinating polycyclic hydrocarbons where direct chlorination frequently leads to unsatisfactory results through the formation of difficultly separable mixtures of chlorine derivatives. The chlorination with dichloroamine-B of benzanthrone, forming 13-chlorobenzanthrone, and of 6-chlorobenzanthrone with the formation of 6,13-dichlorobenzanthrone [11] may be cited as examples.

Experiment has shown that by chlorinating fluorene with N,N-dichlorobenzenesulfonamide it is possible to obtain various individual chlorine derivatives simply ,with good yields. The reaction has been carried out in glacial and aqueous acetic acid and in carbon tetrachloride at different ratios of the reactants. For one mole of fluorene, 0.5, 1 and 2 moles of N,N-dichlorobenzenesulfonamide have been used. The reaction proceeds considerably slower in carbon tetrachloride than in acetic acid, with the participation of free radicals. The products of the reaction in carbon tetrachloride are a mixture of chlorine derivatives which is difficult to separate. The reaction always goes better in acetic acid. If reagents are taken in a ratio of 1 : 2 (dichloramine B), the side-reaction of the formation of fluorenone and its chloro derivatives, intensified in aqueous acetic acid, is observed. At smaller ratios of dichloramine B to fluorene oxidation proceeds to a considerably smaller extent.

With molar ratios of the reactants the main reaction product is 2,7-dichlorofluorene, and the use of half the quantity of dichloramine B leads to the production of 2-chlorofluorene. If two moles of dichloramine B are taken per mole of fluorene, a trichlorofluorene of undetermined structure, possibly representing a product of the addition of chlorine,is formed. A detailed study of this is proceeding. The reaction products are readily isolated as individual substances, which distinguishes our method from the majority of those reported in the literature.

EXPERIMENTAL

Preparation of 2-chlorofluorene. Fluorene (8.3 g) was dissolved in 20 ml of glacial acetic acid in a 3-necked flask fitted with a dropping funnel, a mechanical stirrer, and a reflux condenser and placed on a water bath; the temperature was raised to 80°, and 5.6 g of N,N-dichlorobenzenesulfonamide in 30 ml of glacial acetic acid was added with stirring over 20 min. The given temperature was maintained until active chlorine was no longer present in the reaction mixture (test with potassium iodide). At the end of the reaction, the reaction mixture was treated with water, the precipitate which separated was filtered off, dried and extracted with benzene. The solvent was distilled off, and the residue was recrystallized from alcohol. The yield of 2-chlorofluorene was 5.8 g (58%). M.p. 94-96° (according to the data in the literature, 97° [2]).

Found %: Cl 17.14, 17.06. $C_{13}H_9Cl$. Calculated %: Cl 17.70.

Oxidation with chromic anhydride in glacial acetic acid leads to the formation of 2-chlorofluorenone with m.p. 124-125° (according to data in the literature, 126° [12]).

Preparation of 2,7-dichlorofluorene. To a reaction flask containing 20 ml of glacial acetic acid and 8.3 g of fluorenone was added a solution of 11.3 g of N,N-dichlorobenzenesulfonamide in 30 ml of glacial acetic acid. The reaction vessel was heated to 85° until active chlorine was no longer present in the mixture (about 2 hr). The precipitate separating out from the reaction mass on cooling was filtered off and extracted with benzene, the solvent was distilled off and the dry residue recrystallized from alcohol. The yield of 2,7-dichlorofluorene was 5.2 g (44.5%), m.p. 125-126° (according to data in the literature, 128° [13]).

Found %: Cl 30.42, 30.24. $C_{13}H_8Cl_2$. Calculated %: Cl 30.19.

Oxidation of the 2,7-dichlorofluorene with chromic anhydride in glacial acetic acid led to the formation of 2,7-dichlorofluorenone with m.p. 188-189° (according to data in the literature, 189° [13]).

Preparation of trichlorofluorene. To a reaction flask containing a solution of 8.3 g of fluorene in 55 ml of glacial acetic acid was added a solution of 22.6 g of N,N-dichlorobenzenesulfonamide in 60 ml of glacial acetic acid. The reaction was allowed to proceed at 80° for 15 hr. The precipitate separating out from the reaction mixture on cooling was filtered off and extracted with benzene, the solvent was distilled off and the dry residue recrystallized from alcohol. The yield of trichlorofluorene with m.p. 126-127° was 4.5 g.

Found %: Cl 39.52, 39.61. $C_{13}H_7Cl_3$. Calculated %: Cl 39.46.

Preparation of trichlorofluorene in aqueous acetic acid. Water (60 ml) was added to glacial acetic acid (40g), the reaction vessel was heated to 80°, 8.3 g of fluorene and then, over 10 min, 22.6 g of N,N-dichlorobenzenesulfonamide in 60 ml of glacial acetic acid were added, and the reaction was allowed to proceed at 80° for 17 hr. The reaction mixture was worked up in the same manner as in the previous experiment; 3.4 g of trichlorofluorene with m.p. 126-127° was isolated.

Found %: Cl 39.91, 39.77. $C_{13}H_7Cl_3$. Calculated %: Cl 39.46.

Fluorenone (3.8 g) with m.p. 78-81° (according to data in the literature, 83.5° [14]) was also isolated. Its oxime had m.p. 192-194° (according to data in the literature, 195° [14]).

SUMMARY

1. The reaction of N,N-dichlorobenzenesulfonamide with fluorene has been studied.

2. It has been shown that by changing the ratio of the reactants, 2-chloro-, 2,7-dichloro-, and trichloro-fluorenes may be obtained.

3. The following substances have been isolated and characterized: 2-chlorofluorene and 2,7-dichlorofluorene and the fluorenones corresponding to them, and also fluorenone and a trichlorofluorene of undetermined structure not reported in the literature.

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CYCLOPROPANES AND CYCLOBUTANES

XVIII. p-CYCLOPROPYLCUMENE AND p-ISOPROPENYLCUMENE

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In previous papers it has been shown experimentally by one of us (from the magnitude of the intensity of the characteristic frequencies of the benzene ring in Raman spectra)* that conjugation exists between the benzene ring and the 3-membered ring in arylcyclopropanes [1].

In the present work we have studied the Raman spectra** of aromatic hydrocarbons of the styrene type—p-isopropenylcumene (I) and its isomer, p-cyclopropylcumene (II). A dialkylbenzene with the same hydrocarbon skeleton—p-isopropylcumene (III)—was used as a standard of comparison.

(I)   (II)   (III)
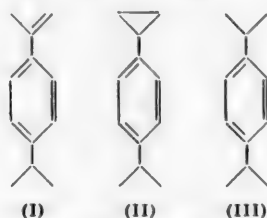
Investigation has shown that an increase in the intensity of the frequencies characteristic for a di-substituted aromatic ring can be observed in the Raman spectrum of p-cyclopropylcumene (in comparison with the spectra of p-isopropylcumene), although this is not so strongly expressed as in the spectrum of p-isopropenylcumene, in which the aromatic ring is conjugated with the double bond of the side chain. Table 1 gives the integral intensities of the characteristic frequencies of the aromatic ring in the spectra of the two synthesized hydrocarbons and in the spectrum of p-isopropylcumene. For comparison, the same data are given for the spectra of mono-substituted benzenes with the same substituents— isopropenylbenzene (α-methylstyrene), cyclopropylbenzene, and isopropylbenzene (cumene).

p-Cyclopropylcumene (II) was obtained by the catalytic decomposition of the corresponding pyrazoline.
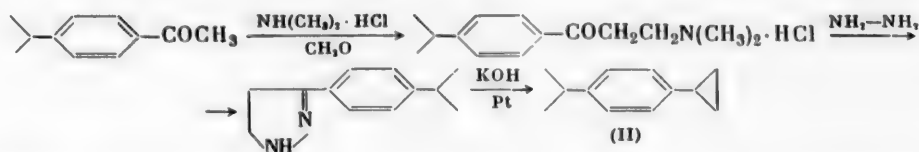
The synthesized hydrocarbon (not reported in the literature) was characterized by its crystalline organomercury compounds (IV)— γ-mercurialcohols—, obtained by the reaction developed by us earlier [5].

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* A similar observation was made simultaneously by B. A. Kazanskii et al. [2].

** A detailed description of the apparatus, the measuring procedure and the calculations used in taking the Raman spectra has been given in one of our previous papers [3]. The photometric determination of the intensities of the spectral lines was carried out on the standard cyclohexane scale, for which the analytical intensity of the 802 cm^{-1} line is taken as 320 units/mole and the integral intensity of this line is 500 units/mole.

$$R = H; \quad X = Cl, \text{ Br, CNS};$$
$$R = CH_3; \quad X = Br.$$
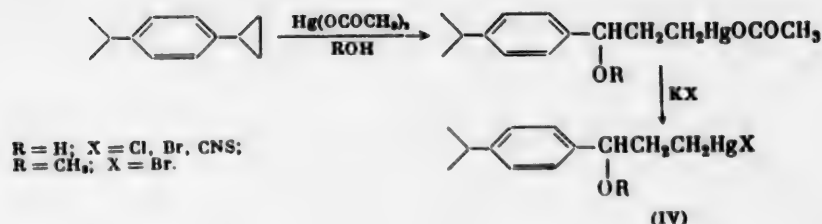
TABLE 1

p-Isopropenylcumene		p-Cyclopropyl-cumene		p-Isopropylcumene [4]	
$\Delta\nu\,cm^{-1}$	I_∞	$\Delta\nu\,cm^{-1}$	I_∞	$\Delta\nu\,cm^{-1}$	I_∞
639 doublet	256	642	213	642	138
1190	560	1190	300	1190	158
1365	556	1364	545	1384 doublet	88
1610	~2700	1613	1585	1617	668
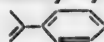
Isopropenylbenzene		Cyclopropyl-benzene [1]		Isopropylbenzene [4]	
$\Delta\nu\,cm^{-1}$	I_∞	$\Delta\nu\,cm^{-1}$	I_∞	$\Delta\nu\,cm^{-1}$	I_∞
1001, 1035	} 1900	1000	1295	1002	720
1300, 1323	} 875	1368	600	1306	90
1600	~2000	1607	920	1606	380

p-Isopropenylcumene (I) was obtained by dehydrating dimethyl p-cumyl carbinol and was also characterized by the preparation of crystalline organomercury compounds—β-mercurialcohols (V).

X = Cl, Br
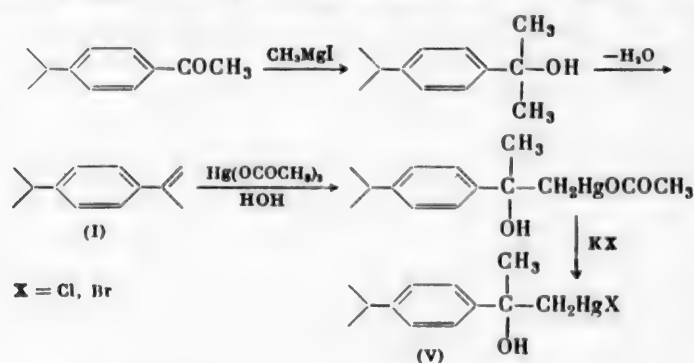
It is of interest to note that the γ-mercurialcohols (IV) from p-cyclopropylcumene melt at a higher temperature than the β-mercurialcohols (V) from p-isopropenylcumene, which are isomeric with them. The β- and γ-mercurialcohols from p-isopropenylcumene and p-cyclopropylcumene are of interest both for use in the identification of hydrocarbons and also for the study of the bacteriostatic activity [6] of these organomercury compounds.

TABLE 2

Isopropenylbenzene (α-methylstyrene)			p-Isopropenylcumene			p-Cyclopropylcumene		
Δν cm⁻¹	I_A	I_∞	Δν cm⁻¹	I_A	I_∞	Δν cm⁻¹	I_A	I_∞
157; b	270	—	180	—	—	228	—	—
239; b	65	—	257	40	—	242	—	—
316	50	—	299; dif	55	—	390	55	122
357—373; db/bkg	90	258	380	—	—	410	0	—
406—413; b	—	—	406	—	—	460	54	60
460	—	—	444	55	—	585	—	—
494	—	—	472	—	—	642	130	213
528	70	} 140	500	—	—	667	0	—
547	—		530	—	—	718	—	—
556	—	—	586	0	—	735	35	—
620	196	320	639	162	} 265	769	338	583
671	—	—	656	—		793	150	} 356
695	0	—	695	0	—	816	} 112	
736	305	465	723	55	—	833		
779	67	—	752	—	—	867	0	—
790	0	—	775	497	750	895	331	710
812	0	—	833	60	116	958	50	100
845; b	56	—	889; b	128	250	998	—	—
898; b	140	270	927	55	116	1020	180	358
929	—		956	60	110	1042; b	} 155	} 350
946	} 120	—	1000	130	300	1056		
965			1055	307	560	1104	95	180
1001	1170	} 1900	1098; dif	} 498	970	1144	—	—
1035	290		1117			1170	55	—
1056	60	—	1190	327	560	1190	250	300
1085	0	—	1217	150	290	1222	452	900
1117	450	810	1267	86	—	1272	75	—
1157	199	360	1296	} 355	930	1308	162	285
1183	146	305	1312			1364	306	545
1217; b	0	—	1365; b	220	556	1434	} 290	512
1270	0	—	1408; b	358	690	1460		
1300; b	} 477	875	1443	175	348	1573	0	—
1323			1460			1613	905	1585
1364	273	—	1610	2175	} 5400*			
1408	475	915	1628	2060				
1443	207	} 403						
1482	145							
1495/bkg	133	—						
1600	1710	} 4050*						
1628	1847							

* With an optical width of the slot ~35 cm⁻¹ the lines at ~1600 and 1628 cm⁻¹ fuse. Judging from the shape of these frequencies on the spectrogram, their integral intensities (I_∞) are approximately the same.

EXPERIMENTAL

p-Cyclopropylcumene was obtained (yield ~65%) by the catalytic decomposition of 3-p-cumylpyrazoline (b.p. 180° at 10 mm; N-nitroso derivative, m.p. 137°; literature data [7]), which was synthesized (yield 54%) by the method of A. N. Kost and V. V. Ershov [7] by the action of hydrazine hydrate and alkali on the hydrochloride of the Mannich base from p-isopropylacetophenone. The hydrocarbon was washed with a 1% solution of potassium permanganate and, after a conventional working up and distillation in a column with 40 theoretical plates, it possessed the following constants:

B.p. 92° (5 mm), n^{20}_D 1.5180, d^{20}_4 0.9158, MR_D 52.89. $C_{12}H_{16}F_3\Delta$. Calculated 52.52; EM_D 0.37.

Found %: C 89.79, 89.78; H 9.98, 10.04. $C_{12}H_{16}$. Calculated %: C 89.95; H 10.05.

Cleavage of the 3-membered ring in p-cyclopropylcumene by reaction with mercury acetate (in aqueous or methanol solution) was carried out by the method described earlier [5]. Crystalline organomercury compounds were obtained.

3-Hydroxy-3-p-cumylpropylmercury chloride: m.p. 108° (from petroleum ether).

Found %: C 35.08, 35.07; H 4.25, 4.20. $C_{12}H_{17}OClHg$. Calculated %: C 34.87; H 4.14.

3-Hydroxy-3-p-cumylpropylmercury bromide: m.p. 116° (from petroleum ether).

Found %: C 31.75, 31.80; H 3.86, 3.89. $C_{12}H_{17}OBrHg$. Calculated %: C 31.48; H 3.74.

3-Hydroxy-3-p-cumylpropylmercury thiocyanate: m.p. 62-63° (from petroleum ether).

Found %: C 35.21, 35.06; H 3.96, 3.95. $C_{13}H_{17}ONSHg$. Calculated %: C 35.81, H 3.93.

3-Methoxy-3-p-cumylpropylmercury bromide: m.p. 53° (from petroleum ether).

Found %: C 32.79, 32.91; H 4.07, 4.17. $C_{13}H_{19}OBrHg$. Calculated %: C 33.10; H 4.06.

Isopropenylbenzene (α-methylstyrene) was obtained by dehydrating dimethyl phenyl carbinol with oxalic acid.

B.p. 54.5-55° (14 mm), $n^{17.5}D$ 1.5384, $n^{20}D$ 1.5360, $d^{17.5}D$ 0.9134, MR_D 40.46. $C_9H_{10}F_4$. Calculated 39.70; EM_D 0.76.

Literature data [8]: B.p. 56° (15 mm), $n^{20}D$ 1.5350, d^{20}_4 0.908.

p-Isopropenylcumene was obtained (yield ~45%) by dehydrating dimethyl p-cumyl carbinol formed (yield 85%) by the reaction of acetyl cumene (b.p. 125° at 10 mm, $n^{20}D$ 1.5250) with methylmagnesium iodide in the presence of oxalic acid. After conventional working up and distillation in the column (40 theoretical plates) the hydrocarbon possessed the following constants:

B.p. 220° (750 mm), $n^{20}D$ 1.5240, d^{20}_4 0.9005, MR_D 54.41. $C_{12}H_{16}F_4$. Calculated 53.55; EM_D 0.86.

Literature data [9]: b.p. 76-77° at 5 mm, $n^{25}D$ 1.5204, d^{25}_{25} 0.889.

The organomercury compounds (β-mercurialcohols) from p-isopropenylcumene were obtained by the same procedure as in the case of p-cyclopropylcumene.

2-Hydroxy-2-p-cumylpropylmercury acetate: m.p. 91.5-92° (from petroleum ether).

Found %: C 39.41, 39.28; H 4.68, 4.66. $C_{14}H_{20}O_3Hg$. Calculated %: C 38.48; H 4.61.

2-Hydroxy-2-p-cumylpropylmercury chloride: m.p. 70° (from petroleum ether).

Found %: C 34.67, 34.51; H 4.05, 4.13. $C_{12}H_{17}OClHg$. Calculated %: C 34.87; H 4.14.

2-Hydroxy-2-p-cumylpropylmercury bromide: m.p. 56° (from petroleum ether).

Found %: C 31.01, 30.95; H 3.95, 3.93. $C_{12}H_{17}OBrHg$. Calculated %: C 31.48; H 3.74.

Raman spectra taken in the present work are given in Table 2.

SUMMARY

1. The presence of conjugation between the 3-membered ring and the aromatic ring in arylcyclopropanes has been confirmed by a comparative study of the intensities of the characteristic frequencies of the aromatic ring in the Raman spectra of p-di-substituted benzenes with similar carbon skeletons (p-isopropenylcumene, p-cyclopropyl-cumene, and p-isopropylcumene).

2. p-Cyclopropylcumene (not previously reported) and p-isopropenylcumene have been characterized by crystalline organomercury compounds—the γ-mercuri- and β-mercurialcohols, respectively.

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INVESTIGATIONS IN THE FIELD OF THE CHEMISTRY
OF DIVINYLACETYLENE AND ITS HALOGEN DERIVATIVES

VI. CIS-TRANS TRANSFORMATIONS OF COMPOUNDS
WITH A DEEPLY SCREENED DOUBLE BOND

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Institute of Organic Chemistry of the Academy of Sciences of the Armenian SSR

We have shown in a previous communication [1] that on chlorinating divinylacetylene, in addition to the known trans-1,2,3,4,5,6-hexachlorohex-3-ene with m.p. 59°, its cis modification with m.p. 91° is also formed. The configurations of the two forms of hexachlorohexene were shown by the ozonolysis, and from the cis-and trans-2,3,4,5-tetrachlorohexa-1,3,5-trienes obtained from them on dehydrochlorination the corresponding cis- and trans-dichloromaleic acids were obtained.

Preliminary experiments which we conducted in the present work showed that neither prolonged (70 hr) irradiation of solutions of trans-hexachlorohex-3-ene in various solvents (hexane, petroleum ether, benzene, acetone, dioxan, 96% alcohol) with a PRK-2 quartz mercury lamp, nor irradiation of a solution of the cis-hexachloro compound in n-hexane with sunlight (10 days) in the presence of traces of iodine, nor irradiation with a quartz mercury lamp (12 hr) lead to their isomerization. The crystals isolated after exposure and removal of solvent had an unchanged melting point. This stability of the modifications of hexachlorohex-3-ene to isomerization must be explained by the deep screening of the double bond present in them. As is well known, in spite of the presence of a double bond in it, hexachlorohex-3-ene does not react with ozone or with hot nitric acid and is not chlorinated even on heating and irradiating [2]. We chose the method of chemical transformation in order to effect the isomerization of the modifications of hexachlorohex-3-ene.

Earlier [3], a substance polymerizing extremely rapidly—3,4-dichlorohexa-1,3,5-triene was obtained by the dechlorination of the hexachlorohex-3-ene with m.p. 59°. It was shown that on chlorinating the dichlorohexatriene obtained, it was converted back into the initial hexachloro compound with m.p. 59°, i.e., no isomerization occurred in the process of dechlorination and rechlorination.

After isolating the new cis-modification of hexachlorohex-3-ene, we subjected it to the above-mentioned reactions of dechlorination and rechlorination. It was found that the dechlorination yielded a dichlorohexatriene differing in its physical constants from the dichlorohexatriene obtained from the trans-hexachloro compound, i.e., the cis-configuration was not disturbed on dechlorination. However, on rechlorination of this dichlorohexatriene, only crystals with m.p. 59° were obtained instead of the initial cis-hexachlorohex-3-ene with m.p. 91°, i.e., isomerization took place on chlorination.
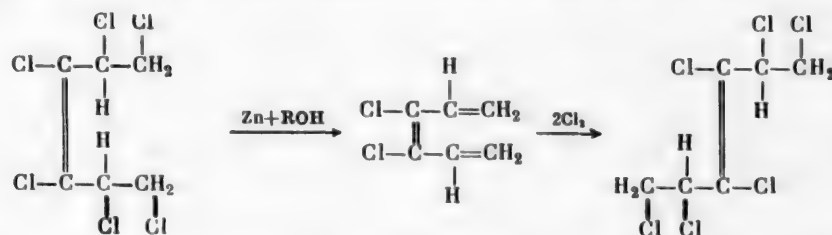
The fact that on chlorination the configuration changes leads to the conclusion that the addition of chlorine takes place not at the 1,2-position (not disturbing the central double bond) and not at the 1,4-position (which would not form 1,2,3,4,5,6-hexachlorohex-3-ene), but most probably first at the 1,6-position and then at the 2,5-position.
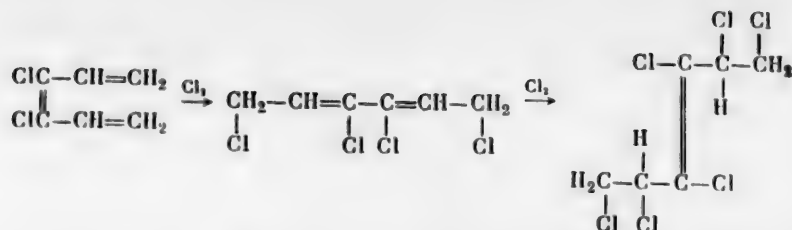
This is somewhat reminiscent of the chlorination of 2,3-dimethylbuta-1,3-diene reported in the literature [4], in which trans-1,4-dichloro-2,3-dimethylbut-2-ene is formed exclusively. This cis-isomer could not be obtained by this method.

In addition to chlorination, bromination of cis- and trans-dichlorohexa-1,3,5-triene was also carried out. In this case the two isomers gave one and the same trans-3,4-dichloro-1,2,5,6-tetrabromohex-3-ene.
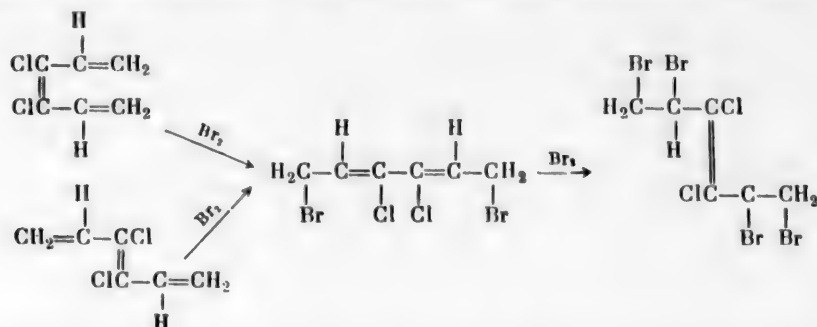
The present paper also gives more precise and more complete physical constants for the trans-3,4-dichlorohexa-1,3,5-triene synthesized previously. A comparison of the physical constants of the cis- and trans-tetrachlorohexa-trienes obtained shows that here also the well known law is followed according to which, in the majority of cases, the boiling point and specific gravity of cis-isomers are higher than for the corresponding trans-isomers.

EXPERIMENTAL

Preparation of cis-3,4-dichlorohexatri-1,3,5-ene. A solution of 15 g of cis-hexachlorohex-3-ene in 75 ml of 96% alcohol and 0.05 g of hydroquinone were placed in a 2-necked round-bottomed flask fitted with a mechanical stirrer, a reflux condenser and a thermometer. Zinc dust (7.5 g) was added in portions through the thermometer neck in such a way that the temperature of the mixture did not exceed 40°. Stirring was continued for 4.5 hr. After the mixture had been filtered and the filtrate poured into water, 6 g (80%) of cis-3,4-dichlorohexa-1,3,5-triene was obtained.

B.p. 56-57° (12 mm), d^{20}_4 1.2278, $n^{20}D$ 1.5787, MR_D 40.31; calc. 38.24.

Found %: Cl 47.83; C 47.76; H 4.16. $C_6H_6Cl_2$. Calculated %: Cl 47.61; C 48.30; H 4.02.

Preparation of trans-3,4-dichlorohexa-1,3,5-triene. The reaction conditions and quantities of reactants were the same as in the preparation of the cis-isomer. The yield of trans-dichlorohexatriene was 6.5 g (85%).

B.p. 52-53° (12 mm), d^{20}_4 1.2175, $n^{20}D$ 1.5798, MR_D 40.675; calc. 38.24.

Chlorination of cis-3,4-dichlorohexa-1,3,5-triene. A solution of 1.5 g of cis-dichlorohexatriene in 20 g of CCl_4 in a small cylindrical reactor cooled externally with ice water was saturated with chlorine, the temperature of the reaction mixture rising to 35°. The increase in weight was 6.5 g . After the solvent had been removed, 2.8 g (96.5%) of crystalline hexachlorohex-3-ene, which after recrystallization from alcohol had m.p. 59°, was obtained. A mixed melting point test with a known sample of trans-1,2,3,4,5,6-hexachlorohex-3-ene gave no depression of the melting point.

Chlorination of trans-3,4-dichlorohexa-1,3,5-triene. Under the reaction conditions for the chlorination of the cis-isomer, a solution of 1.5 g of trans-dichlorohexatriene in 20 g of CCl_4 was saturated with chlorine until the

increase in weight was 5.6 g. The temperature of the mixture rose to 35°. After removing the solvent, 2.9 g (100%) of trans-hexachlorohex-3-ene with m.p. 59° was obtained.

Bromination of cis-3,4-dichlorohexa-1,3,5-triene. Bromine was added dropwise to a solution of 1.5 g of dichlorohexatriene in 20 g of CCl_4 with cooling in ice water; right up to the last drop, the mixture did not cease to lose its color. The weight added was 1.05 g (97.5%). After the solvent had been removed, 1.5 g (95%) of crystals with m.p. 95° (from alcohol) was obtained.

Found%: Cl + Br 83.31; C 15.43; C 15.43; H 1.37. $C_6H_6Cl_2Br_4$. Calculated %: Cl + Br 83.37; C 15.35; H 1.28.

Crystals with m.p. 95° were obtained from trans-dichlorohexatriene under similar conditions with the same yield. A mixed melting point of the 3,4-dichloro-1,2,5,6-tetrabromohex-3-enes obtained by the bromination of cis- and trans-dichlorohexa-1,3,5-trienes gave no depression of the melting point.

SUMMARY

1. Cis-3,4-dichlorohexa-1,3,5-triene has been obtained by the dechlorination with zinc dust of cis-1,2,3,4,5,6-hexachlorohex-3-ene and characterized.

2. It has been shown that on rechlorination both cis- and trans-3,4-dichlorohexa-1,3,5-trienes yield trans-hexachlorohex-3-ene exclusively, i.e., the chlorination of cis-2,3-dichlorohexa-1,3,5-triene gives conditions for isomerization.

3. When cis- and trans-3,4-dichlorohexa-1,3,5-triene are brominated, one and the same 1,2,5,6-tetrabromo-3,4-dichlorohex-3-ene with m.p. 95°, probably of the trans-configuration, is formed.

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N , N - BIS - (β - CHLOROETHYL) - AMINES

OF AMINOCARBOXYLIC ACIDS

I. THE N,N-BIS-(β-CHLOROETHYL)-AMIDE OF GLYCINE

AND COMPOUNDS RELATED TO IT

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The acylated derivatives of N-bis-(β-chloroethyl)-amine have been little studied up to the present time, particularly from the point of view of their biological properties. The synthesis and properties of N,N-bis-(β-chloroethyl)-amides only of some aliphatic and aromatic acids have been reported in published papers [1].

In continuance of our previous work [2], we have undertaken the synthesis of a series of N,N-bis-(β-chloroethyl)-amides of aliphatic aminoacids and their peptides. In the synthesis of these compounds, the first question which arises is the choice of the most favorable methods of protecting the amino groups during the conversion of the carbonyl groups to amide groups. In our work—which we began with glycine—phthalyl and trityl (triphenylmethyl) were used as the protecting groups.

The simplest method for preparing N-bis-(β-chloroethyl)-amides appeared possibly to be the direct action of N-bis-(β-chloroethyl)-amine on any carboxyl group derivative of trityl- or phthalyl glycine. We carried out this reaction using the mixed anhydride and nitrophenyl ester [3] of tritylglycine and the acid chloride of phthalylglycine. No reaction took place in the first two cases, but in the last case the N-bis-(β-chloroethyl)-amide of N'-phthalylglycine was obtained in good yield. However, we did not succeed in using this compound for the preparation of the N-bis-(β-chloroethyl)-amide of glycine, since in attempts to remove the phthalyl group in acid medium it was observed that of the two amide bonds the phthalamide bond was the more stable under these conditions. On heating the N-bis-(β-chloroethyl)-amide of N'-phthalylglycine with 4.5% hydrochloric acid the reaction products were N-phthalylglycine and N-bis-(β-chloroethyl)-amine hydrochloride, and under more severe conditions (20% hydrochloric acid) phthalic acid, glycine hydrochloride, and N-bis-(β-chloroethyl)-amine hydrochloride were formed.

These results and the results of some other orientation experiments obliged us to choose another method of synthesis, namely: first to treat acid derivatives of trityl- or phthalylglycine with diethanolamine, then, with the help of the special methods available for this purpose, to remove the trityl or phthalyl group from the resulting N-bis-(β-hydroxyethyl)-amides to produce the hydrochloride of the N-bis-(β-hydroxyethyl)-amide of glycine, and, finally, to substitute chlorine for the hydroxyl groups of the latter by the action of thionyl chloride.

In carrying out this method of synthesis, the N-bis-(β-hydroxyethyl)-amide of N'-tritylglycine was obtained by the action of diethanolamine on esters (methyl, ethyl and nitrophenyl) of N'-tritylglycine, and the N-bis-(β-hydroxyethyl)-amide of N'-phthalylglycine by the action of the same aminoalcohol on phthalylglycine hydrochloride; the diethanolamine was used in excess. The reaction yielded the corresponding N-bis-(β-hydroxyethyl)-amides. Since the action of acid derivatives with diethanolamine may go in other directions, with the formation of esters and other compounds [4], the structure of the substances obtained was confirmed by means of their infrared spectra, which showed the absorption maximum characteristic for the amide bond(figure), and the absence of contaminants in the materials was shown by means of paper chromatography.

The next stages— the splitting off of the trityl or phthalyl group and the production of the hydrochloride of glycine N-bis-(β-hydroxyethyl)-amide — were carried out without purifying the substances obtained. The hydrochloride of glycine N-bis-(β-chloroethyl)-amide was obtained by the action of thionyl chloride on the unpurified hydrochloride of glycine N-bis-(β-hydroxyethyl)-amide. Since the last two reactions take place in acid medium, in
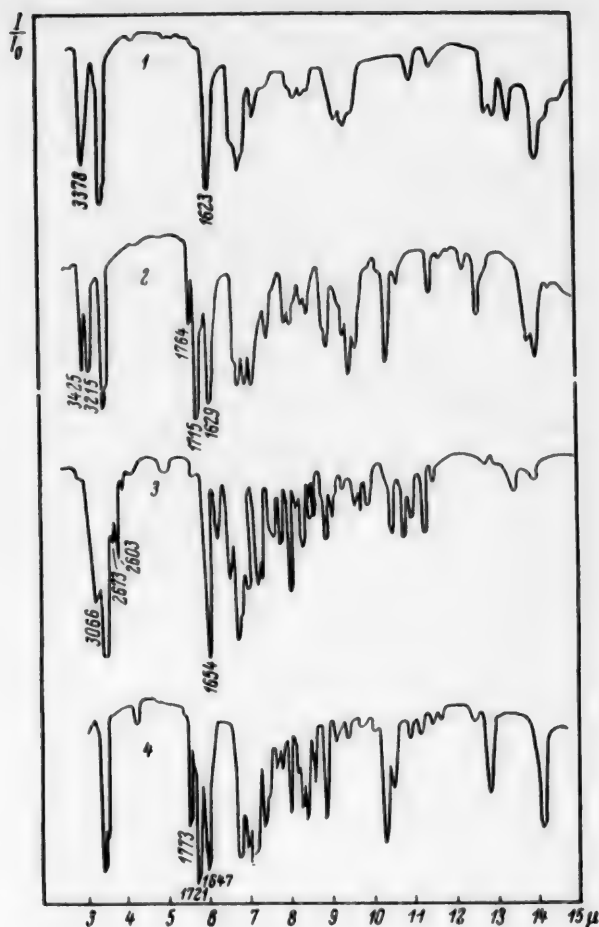
Infrared absorption spectra. 1) The N-bis-(β-hydroxyethyl)-amide of N'-tritylglycine; 2) the N-bis-(β-hydroxyethyl)-amide of N'-phthalylglycine; 3) the hydrochloride of the N-bis-(β-chloroethyl)-amide of glycine; 4) the N-bis-(β-chloroethyl)-amide of N'-phthalylglycine.

consequence of which amide-ester transformation may occur, in this case as well the structure of the substance obtained was confirmed by its infrared absorption spectra ,and the absence of contaminants by means of paper chromatography. After small amounts of the N-bis-(β-chloroethyl)-amide of glycine in alcohol or acetone solutions of hydrogen chloride had been allowed to stand for 2-3 days, unchanged amide was isolated from the solutions.

We attempted to reduce the number of chemical operations in the production of glycine N-bis-(β-chloroethyl)-amide from tritylglycine N-bis-(β-hydroxyethyl)-amide and allowed thionyl chloride to react on the N-bis-(β-hydroxyethyl)-amide without previously eliminating the trityl group, relying on its ready removal in an acid medium. We did in fact succeed in isolating glycine N-bis-(β-chloroethyl)-amide hydrochloride, but in very small amount (22%), since the reaction was accompanied by pronounced resinification. The absence of side reactions in the formation of the N-bis-(β-hydroxyethyl)-amides and the absence of amide-ester rearrangements both in the production of glycine N-bis-(β-chloroethyl)-amide and in the hydrolysis of N'-phthalylglycine N-bis-(β-chloroethyl)-amide indicates the comparative stability of the bond between the acyl carbon atom and the amide nitrogen atom and the low mobility of the chlorine atom. Thus, the amides which we synthesized differ in some respects from the majority of N-bis-(β-chloroethyl)-amides reported in the literature. A number of questions requiring solution arise in connection with our observations: For example, are the properties mentioned above general for similar amides of other aliphatic aminoacids, how are these properties reflected in their biological action, and so on. In any case, we have in the N-bis-(β-chloroethyl)-amides of aminocarboxylic acids, particularly aliphatic ones, a new type of acyl-N-

bis-(β-chloroethyl)-amines, and a more detailed study of these compounds may give new ideas in the field of the connection between the structure of substances and their biological action.

EXPERIMENTAL

1. The p-nitrophenyl ester of N-tritylglycine.* A solution of 1.59 g of N-tritylglycine in 30 ml of anhydrous chloroform containing 0.7 ml of triethylamine was cooled to −5° and 0.38 ml of methyl chloroformate was added to it. After stirring for eight minutes, a solution of 0.69 g of p-nitrophenol in 20 ml of anhydrous chloroform was added. The reaction mixture was stirred at 60° for 20 min and was then cooled, washed four times with water, and dried with anhydrous magnesium sulfate. After the chloroform had been distilled off and the residual substance had been re-crystallized from a mixture of dioxan and water (3 : 1), 1.55 g of the p-nitrophenyl ester of N-tritylglycine with m.p. 149-150° was obtained. Evaporation of the mother liquors yielded a further 0.1 g of substance with m.p. 149-150° (from a mixture of dioxan and water). The total yield was 1.65 g (75.6%). It formed a colorless amorphous substance, soluble in dioxan and chloroform and insoluble in water and ethyl and methyl alcohols.

Found %: C 74.09; H 5.22; N 6.33. $C_{27}H_{22}O_4N_2$. Calculated %: C 73.91; H 5.05; N 6.92.

2. The N-bis-(β-hydroxyethyl)-amide of N'-tritylglycine. a) A mixture of 2.02 g of the p-nitrophenyl ester of N-tritylglycine and 1.04 g of diethanolamine in 25 ml of isoamyl alcohol was heated for six hours at 120-125°. The alcohol was distilled off, the residue washed with water, dried, and recrystallized from a mixture of benzene and alcohol (1 : 1). A yield of 1.64 g (81%) of the N-bis-(β-hydroxyethyl)-amide of N'-tritylglycine with m.p. 127-128° (from a 1 : 1 mixture of benzene and alcohol) was obtained. It formed colorless large prisms, soluble in alcohol, sparingly soluble in benzene, and insoluble in water.

Found %: C 73.98; H 7.02; N 7.05. $C_{25}H_{28}O_3N_2$. Calculated %: C 74.23; H 6.97; N 6.92.

The substance was subjected to paper chromatography: The solvent system was water-butanol; ascending chromatography was used; the chromatograph was run for 13 hr; it was developed with Dragendorff's reagent; the R_f 0.92.

The infrared spectrum ** of N-tritylglycine N'-bis-(β-hydroxyethyl)-amide (figure) had the absorption band characteristic for an amide bond (1623 cm^{-1}).

b) A mixture of 3.31 g of N-tritylglycine methyl ester and 2.1 g of diethanolamine in 30 ml of isoamyl alcohol was heated for 6.5 hr at the boiling point of the alcohol. After cooling, the solvent was distilled off, and the residual oily substance crystallized on rubbing it with a mixture of benzene and methyl alcohol (1 : 1). A yield of 3.55 g (88%) of N'-tritylglycine N-bis-(β-hydroxyethyl)-amide with m.p. 125-126° (from a 1 : 1 mixture of benzene and alcohol) was obtained. A mixture with the substance obtained in the previous experiment melted at 127-128°. The substance was subjected to paper chromatography under the same conditions as in experiment (a); the R_f was 0.94.

c) A mixture of 3.31 g of N'-tritylglycine methyl ester and 3.12 g of diethanolamine was heated at 110-115° for 2.5 hr. The reaction product was worked up in the same way as in experiment (b). A yield of 3.95 g (97.7%) of N'-tritylglycine N-bis-(β-hydroxyethyl)-amide with m.p. 125-126° was obtained. A mixture with the substance obtained in experiment (a) melted at 126-127°; R_f 0.92 [conditions of chromatography the same as for experiment(a)].

d) A mixture of 3.45 g of N'-tritylglycine ethyl ester and 3.15 g of diethanolamine was heated at 110-115° for 2.5 hr. The reaction product was worked up as in experiment (b). A yield of 3.02 g (74.7%) of N'-tritylglycine N-bis-(β-hydroxyethyl)-amide with m.p. 125-126° and R_f 0.90, was obtained. A mixture with the substance obtained in experiment (a) melted at 125-126°.

3. The N-bis-(β-hydroxyethyl)-amide of N'-phthalylglycine. A solution of 2.1 g of diethanolamine in 40 ml of chloroform was added to a solution of 2.24 g of the acid chloride of N'-phthalylglycine in 60 ml of anhydrous chloroform at 18-20°. The reaction mixture was stirred for five hours at the same temperature and was then allowed to stand overnight. The chloroform solution was separated from the oily substance which had deposited on the walls

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* The nitrophenyl ester of N'-phthalylglycine is reported in the literature [3].

** The infrared absorption spectra were taken on an IKS-14 spectrophotometer in the Physical Chemical Laboratory of the S. Ordzhonikidze All-Union Scientific Research Chemicopharmaceutical Institute (VNIKhFI). The substances were used in the crystalline state in the form of suspensions in vaseline oil.

of the flask, the chloroform was distilled off, and the residual amorphous substance was recrystallized from methyl alcohol. A yield of 2.46 g (85%) of the N-bis-(β-hydroxyethyl)-amide of N'-phthalylglycine with m.p. 158-159° (from methyl alcohol) was obtained. It formed colorless crystals, soluble in alcohol and water, very soluble in hot water, and insoluble in benzene.

Found %: C 57.37; H 5.47; N 9.38. $C_{14}H_{16}O_5N_2$. Calculated %: C 57.52; H 5.51; N 9.58.

The infrared absorption spectrum (figure) showed the absorption band of the amide bond (1629 cm^{-1}).

4. Glycine N-bis-(β-chloroethyl)-amide hydrochloride. a) To 15 ml of 75% aqueous acetic acid was added 4.0 g of N'-tritylglycine N-bis-(β-hydroxyethyl)-amide, and the mixture was heated on the boiling water bath for 5 min. The solution obtained was cooled to −10° and the triphenyl carbinol which separated out was filtered off. The mother liquors were evaporated to dryness in vacuo at a temperature not above 50°. Two lots of 10 ml of alcohol were added to the oily substance obtained and the alcohol was distilled off. The residue was treated with 10 ml of alcohol saturated with hydrogen chloride and the alcohol was distilled off. The oily substance obtained was dried by the 4-times repeated addition of a mixture of benzene and alcohol with subsequent evaporation of the solvents. To the oily substance was now added 10 ml of anhydrous benzene and, slowly and dropwise at 0°, 5.6 ml of thionyl chloride. After the evolution of gases had ceased, the reaction mixture was stirred for 20-25 min at room temperature and two hours at 50-55°. Then the benzene and the thionyl chloride were distilled off in vacuo, and the residual substance was washed three times with chloroform. A yield of 2.08 g (88.5%) of glycine N-bis-(β-chloroethyl)-amide hydrochloride with m.p. 146-148° was obtained.. The substance was dissolved in 7 ml of anhydrous methyl alcohol, the solution was boiled with carbon, and filtered from the carbon. After the filtrate had been cooled, 30 ml of anhydrous ether was added to it, and the substance separating out was filtered off. A yield of 1.95 g of glycine N-bis-(β-chloroethyl)-amide hydrochloride with m.p. 151-152° (with decomp.) was obtained.

Found %: C 30.25; H 5.36; N 11.95; Cl 44.88. $C_6H_{12}ON_2Cl_2 \cdot HCl$. Calculated %: C 30.59; H 5.56; N 11.85; Cl 45.15.

The infrared absorption spectra (figure) had the absorption band for an amide bond (1654 cm^{-1}).

b) A solution of 4 g of the N-bis-(β-hydroxyethyl)-amide of N'-phthalylglycine in 40 ml of alcohol and 0.68 ml of a 90% aqueous solution of hydrazine hydrate was boiled for three hours. Then the alcohol was distilled off and the residue was treated with 50 ml of 2 N hydrochloric acid at 40° for five minutes. The insoluble phthalyl hydrazide was filtered off and the filtrate evaporated in vacuo at a temperature not exceeding 50°. The residual oily substance was dried by a 4-times repeated addition of a mixture of benzene and alcohol with subsequent evaporation of the solvents. Then 10 ml of anhydrous benzene and, at 0°, 5.6 ml of thionyl chloride were added to the oily substance. The other reaction conditions were the same as in experiment (a). A yield of 1.80 g (76.5%) of the hydrochloride of the N-bis-(β-chloroethyl)-amide of glycine with m.p. 147-149° (with decomp.) was obtained. After purification, carried out as in experiment (a), 1.68 g of a substance with m.p. 150-151° (with decomp.) was obtained. A mixture with the glycine N-bis-(β-chloroethyl)-amide hydrochloride obtained in experiment (a) melted at 150-151°.

5. The N-bis-(β-chloroethyl)-amide of N'-phthalylglycine. A solution of bis-(β-chloroethyl)-amine (the base was obtained from 3.57 g of the hydrochloride by treatment of the latter with a cooled saturated solution of sodium carbonate and extraction with chloroform [4]) was added at 18-20° to a solution of 2.24 g of N'-phthalylglycine hydrochloride in 40 ml of anhydrous chloroform. The reaction mixture was stirred at 18-20° for six hours and was then allowed to stand overnight. The substance which separated out was filtered off, and 1.7 g of bis-(β-chloroethyl)-amine hydrochloride was obtained. The chloroform solution was evaporated to dryness in vacuo and the residual substance was recrystallized from ethyl acetate. A yield of 3.78 g (87.6%) of N'-phthalylglycine N-bis-(β-chloethyl)-amide with m.p. 142-143° (from ethyl acetate) was obtained. It formed colorless needles, soluble in hot ethyl acetate and insoluble in water.

Found %: C 50.91; H 4.26; N 8.49; Cl 21.54. $C_{14}H_{14}O_3N_2Cl_2$. Calculated %: C 51.07; H 4.28; N 8.51; Cl 21.57.

The absorption band of the amide bond (1647 cm^{-1}) was found in the infrared spectrum (figure).

The hydrolysis of N'-phthalylglycine N-bis-(β-chloroethyl)-amide. a) A suspension of 2.0 g of N'-phthalylglycine N-bis-(β-chloroethyl)-amide in 10 ml of a 20% aqueous solution of hydrochloric acid was heated for three

hours at 90-95°. At the commencement of heating, all the material went into solution and then, after one hour, a white amorphous substance separated out. The latter was filtered off after the reaction mixture had been cooled. A substance (A) and mother liquors (A) were obtained. After repeated crystallization of substance (A) from water, 0.9 g (89%) of o-phthalic acid with m.p. 190-191°, giving no depression of the melting point in admixture with authentic o-phthalic acid, was obtained. The aqueous mother liquors remaining after the separation of the o-phthalic acid were combined and evaporated in vacuum to half their initial volume. The substance separating out was filtered off. A substance (B) and mother liquors (B) were obtained. After two recrystallizations of substance (B) from water, 0.1 g (8%) of N'-phthalylglycine with m.p. 191°, giving no depression of the melting point admixture with N'-phthalylglycine, was obtained. The mother liquors (B) were evaporated in vacuo. A yield of 0.5 g (74.6%) of a substance of m.p. 184°, giving no depressing of the melting point in admixture with glycine hydrochloride, was obtained.

The hydrochloric acid mother liquors (A) were evaporated in vacuo; the residual oily substance was dissolved in 10 ml of alcohol, 20 ml of ether was added to the alcoholic solution and the mixture was allowed to stand for 24 hr in a refrigerator at −5°. The crystalline substance which separated out was filtered off. A yield of 0.86 g (80%) of bis-(β-chloroethyl)-amine hydrochloride with m.p. 214-216° (from a 98 : 2 mixture of ethanol and acetone) was obtained. A mixed melting point test with a known sample of bis-(β-chloroethyl)-amine hydrochloride melted at 214-216°.

b) A suspension of 2.0 g of N'-phthalylglycine N-bis-(β-chloroethyl)-amide in 10 ml of a 4% aqueous solution of hydrochloric acid was heated at 90-95° for 1.5 hr. The insoluble substance was filtered off from the hot solution. A recovery of 0.8 g of the initial substance with m.p. 142-143° was obtained. A mixture with N'-phthalylglycine N-bis-(β-chloroethyl)-amide melted at 142-143°. The mother liquors (A) remaining after the separation of the initial substance were cooled, and the substance separating out was filtered off. A substance (B) with m.p. 189-190° (0.73 g) and mother liquors (B) were obtained. Substance (B) was recrystallized from water. A yield of 0.65 g (81.8%) of N-phthalylglycine with m.p. 190-191° was obtained. A mixture with a known sample of N-phthalylglycine gave no depression of the melting point. The mother liquors (B) were evaporated to dryness in vacuo; the oily substance was dried by adding a mixture of alcohol and benzene and subsequently distilling off the solvents. Then the oily substance was dissolved in 10 ml of alcohol and 20 ml of ether was added to the solution. The crystalline substance which separated out was filtered off and dried. A yield of 0.51 g (78.3%) of bis-(β-chloroethyl)-amine hydrochloride with m.p. 214-216° (from a 98 : 2 mixture of ethanol and acetone) was obtained. A mixture with bis-(β-chloroethyl)-amine hydrochloride gave no depression of the melting point.

SUMMARY

Glycine N-bis-(β-chloroethyl)-amide hydrochloride has been obtained and its stability in an acid medium has been established.

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THE PREPARATION OF ORGANOSILICON DERIVATIVES

OF BICYCLO-(2,2,1)-HEPTANE

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Recently a number of communications have been published on the preparation of polymers of bicyclo-(2,2,1)-hept-2-ene [1] and bicyclo-(2,2,1)-hepta-2,5-diene [2], distinguished by their high thermal stability. These results induced us to investigate the possibility of synthesizing organosilicon monomers with the same bicyclic radicals.

There have been publications in the literature on the synthesis of a similar type of organosilicon monomers by the diene synthesis. 2-(Trichlorosilyl)-bicyclo-(2,2,1)-hept-5-ene has been obtained from cyclopentadiene and vinyltrichlorosilane [3] and 2-(ethyldiethoxysilyl)-bicyclo-(2,2,1)-hept-5-ene by boiling a mixture of vinylethyldiethoxysilane and dicyclopentadiene [4]. A series of organosilicon monomers was synthesized by the Diels—Alder reaction from hexachlorocyclopentadiene and 5,5-difluorotetrachlorocyclopentadiene and various vinylethoxysilanes and vinylchlorosilanes [5, 6]. There is information on an analogous reaction in the patent literature [7, 8]. Organosilicon derivatives of bicyclo-(2,2,1)-heptanecarboxylic acid have also been obtained [9, 10].

In our own work we have profited by a wide study of the addition reactions of silicon hydrides to unsaturated compounds in the presence of chloroplatinic acid [9]. Trichlorosilane, methyl-, ethyl-, and N-propyldichlorosilanes and diethylchlorosilanes have been used as silicon hydrides. The following compounds have now become available as unsaturated bicyclic compounds [11]: bicyclo-(2,2,1)-hept-2-ene, bicyclo-(2,2,1)-hepta-2,5-diene, 2-methyl-bicyclo-(2,2,1)-hept-5-ene, 2-vinylbicyclo-(2,2,1)-hept-5-ene, and the dimer of cyclopentadiene.

The reaction of trichlorosilane, methyldichlorosilane, and ethyldichlorosilane, with bicyclo-(2,2,1)-hept-2-ene was carried out successfully at 30-60°, the yields of the products of addition of the silicon hydrides to the hydrocarbon amounting to about 50%.

$$R = H; CH_3; C_2H_5.$$
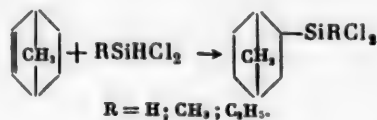
In the reaction of bicyclo-(2,2,1)-hept-2-ene with trichlorosilane, in addition to 2-(trichlorosilyl)-bicyclo-(2,2,1)-heptane, a compound was also formed from two molecules of bicyclo-(2,2,1)-hept-2-ene and one molecule of trichlorosilane.

The presumed radical nature of the reaction may be represented by the following reaction scheme:
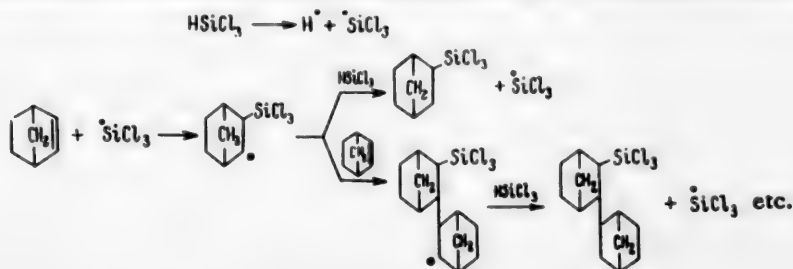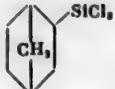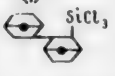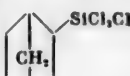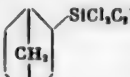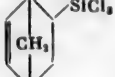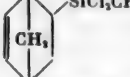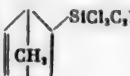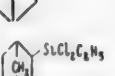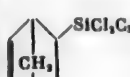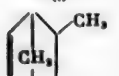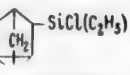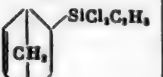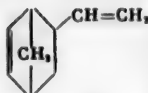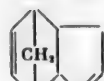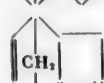
TABLE 1. The Action of Hydrocarbons with Siliconhydride

Initial substances		Compound obtained	Reaction temperature	Reaction time (in hours)	Yield (in %)	Boiling point (pressure in mm)	n_D^{20}
No. / hydrocarbon	silicon-hydride						
1 — (ring, CH_3)	$HSiCl_3$	(ring, CH_3, $SiCl_3$)	30–40°	3	27.3	63.5° (4.5)	1.4919
		(bicyclic, $SiCl_3$)	30—40	3	20.1	159—161 (5)	1.5295
2 — (ring, CH_3)	CH_3SiHCl_2	(ring, CH_2, $SiCl_2CH_3$)	40—50	12	53	114—118 (3)	1.4860
3 — (ring, CH_3)	$C_2H_5SiHCl_2$	(ring, CH_2, $SiCl_2C_2H_5$)	40—65	16	52.6	119—120 (8)	1.4900
4 — (ring, CH_3)	$HSiCl_3$	(ring, CH_3, $SiCl_3$)	70 (pressure 1.5 atm)	3.5	44.3	70—74 (6.5)	1.4988
5 — (ring, CH_3)	CH_3SiHCl_2	(ring, CH_3, $SiCl_2CH_3$)	45—55	5	80.0	74—75 (10)	1.4938
6 — (ring, CH_2)	$C_2H_5SiHCl_2$	(ring, CH_3, $SiCl_2C_2H_5$)	55—60	3—4	71.3	89—90 (8)	1.4955
		(ring, CH_2, $SiCl_2C_2H_5$)					
7 — (ring, CH_3)	$C_3H_7SiHCl_2$	(ring, CH_3, $SiCl_2C_3H_7$)	65—75	5	20.5	87—88 (3)	1.4880
		(ring, CH_2, $SiCl_2C_3H_7$)					
8 — (ring, CH_3)	$(C_2H_5)_2SiHCl$	(ring, CH_2, $SiCl(C_2H_5)$)	50	17	20.0	90—97 (6)	1.4925
9 — (ring, CH_3, CH_3)	$HSiCl_3$	$C_9H_{11}SiCl_3$	30	2	20.0	98—100 (9)	1.4988
10 — (ring, CH_3, $SiCl_3C_2H_5$)	$C_2H_5SiHCl_2$	$C_{11}H_{20}Si_2Cl_4$	40	3	37.0	148—151 (3.5)	1.5031

d_4^{20}	MR_D		Empirical formula	Calculated (%)				Found (%)			
	found	calcu-lated		C	H	Cl	Si	C	H	Cl	Si
1.2678	52.47	52.69	$C_7H_{11}SiCl_3$	36.62	4.79	46.37	12.20	37.43, 37.37	5.20, 5.11	44.74, 44.51	11.93, 12.25
1.2554	79.53	80.84	$C_{11}H_{11}SiCl_3$	51.93	6.48	32.91	8.68	52.46, 52.46	6.97, 6.77	32.23, 32.32	—, 9.09
1.1337	52.91	53.06	$C_8H_{11}SiCl_3$	—	—	—	—	—	—	—	—
1.1288	57.18	57.69	$C_8H_{16}SiCl_2$	48.43	7.17	31.80	12.60	48.46, 48.65	7.45, 7.18	31.36, 31.38	12.56, 12.51
1.2973	51.47	52.22	$C_7H_9SiCl_3$	—	—	—	—	—	—	—	—
1.1513	51.32	52.59	$C_8H_{14}SiCl_2$	46.39	5.79	34.26	13.53				
1.1530			$C_8H_{11}SiCl_2$	48.89	6.33	32.09	12.67	48.78, 48.88	6.26, 6.34	30.83, 30.27	12.81, 12.63
1.1199			$C_{10}H_{16}SiCl_2$	—	—	—	—	—	—	—	—
1.0416	59.78	59.72	$C_{11}H_{15}SiCl$	—	—	—	—	—	—	—	—
1.2973	51.47	52.22	$C_8H_{11}SiCl_3$	—	—	Cl	—	—	—	Cl	Si
1.2273	84.27	84.40	$C_{11}H_{20}Si_2Cl_4$	37.71	5.71	40.47	16.01	38.07, 38.00	6.02, 5.95	39.75, 39.75	16.25, 16.30

TABLE 1 (Cont'd)

Initial substances		Compound obtained	Reaction temperature	Reaction time (in hours)	Yield (in %)	Boiling point (pressure in mm)	n_D^{20}
hydrocarbon	silicon-hydride						
11 (structure with CH=CH₂, CH₂)	HSiCl₃	C₉H₁₃SiCl₃	30	8	35.8	110 (11)	1.5010
12 (structure with CH₂)	HSiCl₃	C₁₀H₁₃SiCl₃	30—40	12—14	61.4	121—123 (5)	1.5205
13 (structure with CH₂)	CH₃SiHCl₂	C₁₁H₁₆SiCl₂	40	5	57.0	138—149 (5.5)	1.5193
14 (structure with CH₂)	C₂H₅SiHCl₂	C₁₁H₁₈SiCl₂	60	10	38.4	140—154 (5)	1.5193

The reactions with bicyclo-(2,2,1)-hepta-2,5-diene proceeded in a more complex manner. Under mild conditions, (atmospheric pressure, temperature 30-40°) this hydrocarbon did not react with trichlorosilane. The reaction went only on heating the reaction mixture to 70° in an autoclave (1.5 atm.). The yield of 2-(trichlorosilyl)-bicyclo-(2,2,1)-hept-5-ene amounted to 44%. Methyl-, ethyl-, and propyldichlorosilanes, and diethylsilane, added to the bicyclopentadiene at atmospheric pressure and 45-70°, gave adducts with yields of 20-80%.

The spectral method of analysis was used to establish the structure of the compounds obtained. Whereas in the case of the reaction of silicon hydrides with bicyclo-(2,2,1)-hept-5-ene it was possible to expect the formation of adducts of only a single definite structure (norbornylene type), when bicyclo-(2,2,1)-hepta-2,5-diene is used, the

formation of products both of the norbornylene type $\left[\begin{array}{c} \text{(structure, CH}_2\text{)} R \end{array}\right]$, and of products of the conversion of the latter into

the nortricyclene type $\left[\begin{array}{c} \text{(structure, CH}_2\text{)} R \end{array}\right]$ [12, 13] is possible.

It is known from data in the literature that substances of the nortricyclene type have a characteristic frequency in the Raman spectra and a characteristic peak in the 12.3-12.5 μ region in the infrared spectra [13-16]. The most characteristic frequency in the Raman spectra for compounds of the norbornylene type is a frequency of 1570-1575 cm⁻¹, i.e., a frequency corresponding to the valence vibrations of a double bond [17]. In the Raman spectra of the products of the addition of trichlorosilane and methyldichlorosilane to bicyclo-(2,2,1)-hepta-2,5-diene, there are very intense frequencies at 1575 cm⁻¹ [8] and 1572 cm⁻¹ (9p), and the frequency 800-810 cm⁻¹ is absent.

$$\text{(structure, CH}_2\text{)} + \text{RSiHCl}_2 \longrightarrow \text{(structure, CH}_2\text{)}-\text{SiRCl}_2$$
$$R = H, CH_3.$$
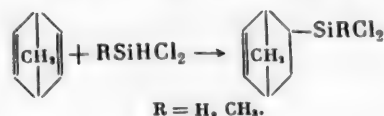
2-(Methyldichlorosilyl)-bicyclo-(2,2,1)-hept-5-ene was synthesized by an alternative route using the diene synthesis from methylvinyldichlorosilane and cyclopentadiene.

$$\text{(structure)} + \underset{\overset{\|}{\text{CH}_2}}{\text{CH}}-\text{SiCH}_3\text{Cl}_2 \longrightarrow \text{(structure, CH}_2\text{)}-\text{SiCH}_3\text{Cl}_2;$$
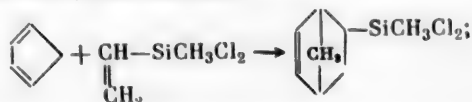
The Raman spectrum of this substance proved to be identical with the Raman spectrum which we obtained for the product of the addition of methyldichlorosilane to the bicycloheptadiene. Moreover, hydrogenation of the latter compound in the presence of platinum black in the cold showed that one double bond is present in its molecule. Con-

d_4^{20}	MR_D		Empirical formula	Calculated (%)				Found (%)			
	found	calculated		C	H	Cl	Si	C	H	Cl	Si
1.2225	61.51	61.48	$C_9H_{13}SiCl_3$	27.63	3.58	54.95	14.43	28.04, 28.20	3.84, 4.05		14.74, 14.73
1.2880	63.55	63.98	$C_{10}H_{15}SiCl_3$	44.86	4.86	39.82	10.47	45.29, 45.11	5.09, 4.97	39.01, 38.62	10.60, 10.47
1.1723	64.32	64.35	$C_{11}H_{16}SiCl_3$								
1.1748	67.47	68.98	$C_{12}H_{19}SiCl_3$	55.19	6.90	27.03	10.77	55.42, 55.29	6.95, 7.09	27.43, 27.37	10.30, 10.42

sequently, on the basis of the results obtained with the products of the addition of $HSiCl_3$ and CH_3SiHCl_2 to bicycloheptadiene, it is right to assign to them a structure of the norbornylene type:

$$\langle\!\langle\ \rangle\!\rangle_{CH_2}\!-SiCl_3 \quad \text{and} \quad \langle\!\langle\ \rangle\!\rangle_{CH_2}\!-SiCH_3Cl_2$$
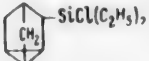
In the Raman spectra of the products of addition of ethyl- and propyldichlorosilane to bicyclopentaheptadiene, both the frequencies 1570-1575 cm⁻¹ and the frequencies 801-807 cm⁻¹ are observed, even if the 801-807 cm⁻¹ frequency is stronger in the first case (its intensity is 7 units, and the intensity of the 1575 cm⁻¹ frequency 5 units), and in the second case the 1570 cm⁻¹ frequency (9p) is more intense than the 808 cm⁻¹ frequency (1 unit).

The adduct of ethyldichlorosilane and bicycloheptadiene was ethylated with C_2H_5MgBr. Hydrogenation of the silicohydrocarbon obtained over platinum black showed the presence in it of only 35% of a compound with one double bond. On hydrogenating the adduct of propyldichlorosilane and bicycloheptadiene, about 80% of a compound with one double bond was found in it. Thus, in these two cases, the adducts are mixtures of compounds of the norbornylene and nortricyclene types.

$$\langle\!\langle\ \rangle\!\rangle_{CH_2}\!-SiCl_2C_2H_5 \quad \text{and} \quad \langle\!\langle\ \rangle\!\rangle_{CH_2}\!-SiCl_2C_2H_5 \quad \langle\!\langle\ \rangle\!\rangle_{CH_2}\!-SiCl_2C_3H_7 \quad \text{and} \quad \langle\!\langle\ \rangle\!\rangle_{CH_2}\!-SiCl_2C_3H_7$$

In the first case the structure of the nortricyclene type predominates, and in the second case the mixture contains an overwhelming amount of the compound with the norbornylene structure.

In the Raman spectra of the product of addition of diethylchlorosilane to bicycloheptadiene, the 1570-1575 cm⁻¹ frequency is lacking and there is an intense frequency at 794 cm⁻¹ [7] which, probably in the given case is characteristic for a compound of the nortricyclene type (it is lowered in comparison with the normal value by about 10 cm⁻¹).

Consequently, this adduct has the nortricyclene type of structure $\langle\!\langle\ \rangle\!\rangle_{CH_2}\!-SiCl(C_2H_5)_2$, i.e., the conversion in this case proceeds to completion.

The reaction of trichlorosilane with 2-methylbicyclo-(2,2,1)-hept-5-ene yielded 20% of an adduct which, apparently, is a mixture of the 2-methyl-(trichlorosilyl)-bicycloheptanes with the trichlorosilyl group in positions 5 and 6.
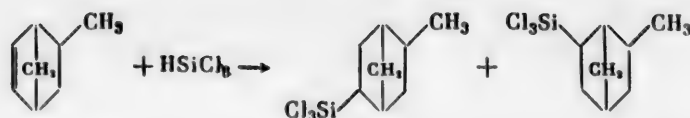
The adducts of various silicon hydrides with 2-vinylbicyclo-(2,2,1)-hept-5-ene and the dimer of cyclopentadiene are also mixtures of substances, since, in these cases the addition of the silyl groups may take place at different double bonds and also in different positions (5 or 6) of the bicycloheptene part of the molecule. In the case of the reaction of trichlorosilane with 2-vinylbicyclo-(2,2,1)-hept-5-ene, it has been shown from spectra that the addition of the $HSiCl_3$ takes place at both double bonds in approximately similar proportions.

The more detailed structure of the adducts obtained was not investigated.

In the reaction of silicon hydrides with the abovementioned hydrocarbons, in addition to the formation of isomers by the addition of the silyl groups to the different carbon atoms connected by the double bond, the formation of endo- and exo-isomers is also theoretically possible. And the fact that all the reactions of homolytic addition to carbon—carbon double bonds studied stereochemically up to the present time are trans-additions [18] does not help in deciding the question of the preferential formation of endo- or exo-isomers in the cases which we have studied.

TABLE 2

Siloxane liquid	Freezing point	n_D^{30}	d_4^{30}	Molecular wt.	Viscosity (in cst) 20°	50°	100°
$(CH_3)_3SiO-\left[\begin{array}{c} CH_3 \\ -Si-O- \\ C_6H_5 \end{array}\right]_n -Si(CH_3)_3$	—39°	1.5162	1.0624	755	52.08	18.11	5.90
$(CH_3)_3SiO-\left[\begin{array}{c} CH_3 \\ -Si-O- \\ CH_2 \\ C_6H_5 \end{array}\right]_n -Si(CH_3)_3$	—20	1.5250	1.0654	754	148.0	36.04	9.09
$(CH_3)_3SiO-\left[\begin{array}{c} CH_3 \\ -Si-O- \\ (CH_2)_2 \\ C_6H_5 \end{array}\right]_n -Si(CH_3)_3$	—45	1.5138	1.0341	881	68.5	24.68	7.91
$(CH_3)_3SiO-\left[\begin{array}{c} CH_3 \\ -Si-O- \\ \end{array}\right]_n -Si(CH_3)_3$	—8	1.4990	1.0457	797	3116.0	328.8	32.8

The results of the experiments are given in Table 1.

Silicon hydrides could not be added to cyclopentadiene in the presence of chloroplatinic acid under the conditions which we used. There is information in the literature on the thermal addition of silicon hydrides to cyclopentadiene [19, 20].

Co-hydrolysis of the 2-(methyldichlorosilyl)-bicyclo-(2,2,1)- heptane obtained with trimethylchlorosilane yielded a siloxane liquid. Siloxane liquids were prepared from methylphenyl-, methylbenzyl-, and methyl-β-phenylethyldichlorosilanes in order to compare their properties. The liquids synthesized corresponded to compounds of

the type $(CH_3)_3Si-O-\left[\begin{array}{c} CH_3 \\ | \\ -Si-O- \\ | \\ R \end{array}\right]_n -Si(CH_3)_3$ with a mean value of $n = 4$. The methyl-β-penylethyl-

siloxane liquid has the lowest freezing point ($-45°$) and the methylbicycloheptylsiloxane liquid the highest ($-8°$). The methylbicycloheptyl liquid also possesses the sharpest change in viscosity with change of temperature.

The freezing point, the refractive index, the specific gravity, the molecular weight, and the viscosities at 20, 50, and 100° of the liquids obtained are given in Table 2.

EXPERIMENTAL

Reaction of trichlorosilane with bicyclo-(2,2,1)-hepta-2,5-diene. In a 60 ml experimental steel autoclave were placed 15 g of bicyclo-(2,2,1)-hepta-2,5-diene, 22 g of trichlorosilane, and 0.5 ml of a 0.1 M solution of H_2PtCl_6 in isopropyl alcohol. The mixture was heated for 3.5 hr at 70°. The highest pressure produced in the autoclave was 1.5 atm. On distillation, 16 g of 2-(trichlorosilyl)-bicyclo-(2,2,1)-hept-5-ene was obtained. The yield and constants of the reaction product are given in Table 1. For literature data see [3].

Reaction of methyldichlorosilane with bicyclo-(2,2,1)-hepta-2,5-diene. The reaction was carried out in a four-necked flask fitted with a stirrer with seal, a dropping funnel, reflux condenser, and thermometer. In the flask were placed 30.6 g of bicyclo-(2,2,1)-hepta-2,5-diene and 0.2 ml of a 0.1 M solution of H_2PtCl_6 in isopropyl alcohol. After the addition of a few milliliters of methyldichlorosilane, an exothermic reaction commenced, as a result of which a sharp rise in the temperature of the reaction mixture by 10-30° was observed. If the reaction did not begin, the mixture was heated to 40-50° and maintained at this temperature until it did begin. After the reaction had begun, the remaining quantity of methyldichlorosilane was added slowly. In all, 38.7 g of methyldichlorosilane was added over 40 min. Then the mixture was heated at 40-50° for another four hours, after which it was distilled. The distillation yielded 55 g of 2-(methyldichlorosilyl)-bicyclo-(2,2,1)-hept-5-ene (Table 1 substance 5). The reaction of other silicon hydrides with unsaturated compounds was carried out under similar conditions. The temperature of the reaction mixture and the time of heating, together with the yields, analyses, and properties of the adducts obtained are given in Table 1 for all cases.

Condensation of cyclopentadiene with methylvinyldichlorosilane. A mixture of 18.2 g of cyclopentadiene and 39.0 g of methylvinyldichlorosilane was heated for three hours to 130° in a flask with a reflux condenser and then at 130° for a further 30 min. On distillation, 28.5 g (50%) of 2-(methyldichlorosilyl)-bicyclo-(2,2,1)-hept-5-ene was obtained.

B.p. 98-98.5° (20 mm), $n^{20}D$ 1.4953, d^{20}_4 1.1703, MR_D 51.71; calc. 52.59.

Reaction of some alkylsilane chlorides with Grignard reagents. A mixture of 2-(ethyldichlorosilyl)-bicyclo-(2,2,1)-hept-5-ene and 3-(ethyldichlorosilyl)-tricyclo-(2,2,1,0$^{2.6}$)-heptane, obtained by the interaction of ethyldichlorosilane and bicyclo-(2,2,1)-hepta-2,5-diene, was added to C_2H_5MgBr (a 1.2-fold excess). After the usual working up and distillation, a mixture of 2-(triethylsilyl)-bicyclo-(2,2,1)-hept-5-ene and 3-(triethylsilyl)-tricyclo-(2,2,1,0$^{2.6}$)-heptane was obtained; yield 72%, b.p. 88-90° (5 mm), $n^{20}D$ 1.4839, d^{20}_4 0.9447.

A mixture of 2-(β-trimethylsilylethyl)-bicyclo-(2,2,1)-hept-5-ene and 2-vinyl-5(6)-trimethylsilylbicyclo-(2,2,1)-heptane was obtained in a similar way from the product of the reaction of trichlorosilane and 2-vinylbicyclo-(2,2,1)-hept-5-ene and CH_3MgBr. Yield 78%.

B.p. 106.3-107.0 (20 mm), $n^{20}D$ 1.4670, d^{20}_4 0.8652, MR_D 62.34; calc. 62.59.

Found %: C 74.37, 74.34; H 11.57, 11.47; Si 14.26, 14.06. $C_{12}H_{22}Si$. Calculated %: C 74.16; H 11.39; Si 14.45.

Hydrogenation of some of the compounds obtained. a) Hydrogenation of 2-methyldichlorosilyl-(2,2,1)-hept-5-ene (I). Substance (I) (1.4284 g) in 3 ml of anhydrous alcohol was hydrogenated in the cold in the presence of 0.1 g of platinum black. Theoretically, 168 ml of H_2 (760 mm, 0°) should be absorbed; actually 156 ml of H_2 (760 mm, 0°) was absorbed, which corresponds to a content of 93% of a compound with a single double bond.

b) Hydrogenation of a mixture of 2-(triethylsilyl)-bicyclo-(2,2,1)-hept-5-ene (II) and 3-(triethylsilyl)-tricyclo-(2,2,1,0^{2,6})-heptane. A mixture of 1.108 g of substance (II) in 3 ml of anhydrous alcohol and 0.1 g of platinum black was used. In theory, 119 ml of H_2 (760 mm, 0°) should be absorbed; actually 42 ml of H_2 (760 mm, 0°) was absorbed, which corresponds to a content of 35% of a compound with one double bond.

c) Hydrogenation of a mixture of 2-(propyldichlorosilyl)-bicyclo-(2,2,1)-hept-5-ene (III) and 3-(propyldichlorosilyl)-tricyclo-(2,2,1,0^{2,6})-heptane. A mixture of 1.9506 g of the substance (III) in 5 ml of cyclohexane and 0.1 g of platinum black was used. In theory, 186 ml of H_2 (760 mm, 0°) should be absorbed; actually 152 ml of H_2 (760 mm, 0°) was absorbed, which corresponds to a content of 82% of a compound with one double bond. In a second experiment with a 2.3478 g sample of compound (III), 223 ml of H_2 (760 mm, 0°) should have been absorbed, and 172 ml of H_2 (760 mm, 0°) was actually absorbed, which correponds to a content of 77% of a compound with one double bond.

Co-hydrolysis of methylphenyldichlorosilane and trimethylchlorosilane. The reaction was carried out in a flask fitted with a stirrer with seal, reflux condenser, dropping funnel, and thermometer. In the flask was placed 118.8 g of water. A mixture of 30 g of methylphenyldichlorosilane and 3.25 g of trimethylchlorosilane was added gradually with vigorous stirring. The temperature of the reaction mixture was maintained at 10°. At the end of the reaction the products were extracted with ether. The ethereal extracts were washed with water to neutrality, and the ether was then distilled off. The liquid obtained was heated for five hours at 150° in the presence of 1 g of powdered NaOH. Then an ethereal solution was washed with water to neutrality, dried over $CaCl_2$, and the ether was distilled off. To remove light fractions, the liquid was heated to 100° in a vacuum of 3-4 mm.

The other siloxane liquids were obtained in a similar manner. Their properties are given in Table 2.

Raman spectra of the compounds obtained. The spectra were obtained in the Russian RSP-51 apparatus. The intensities of the lines were evaluated visually on a 10-point scale. The Raman spectra of a number of compounds obtained are given below.

I. 2-(Trichlorosilyl)-bicyclo-(2,2,1)-hept-5-ene.

145 (8v.broad), 170 (6 broad), 197 (8 broad), 264 (4), 324 (10 sh), 336 (5), 379 (4), 438 (1), 455 (1), 494 (8), 707 (1), 804 (0), 892 (0), 904 (0), 931 (3), 953 (0), 962 (0), 985 (2), 1039 (3), 1066 (0), 1097 (8), 1138 (5), 1150 (4), 1175 (0), 1212 (0), 1286 (1), 1443 (0), 1575 (8).

II. 2-(Methyldichlorisilyl)-bicyclo-(2,2,1)-hept-5-ene.

146 (9), 175 (1), 210 (10 broad), 270 (4), 330 (4), 362 (4), 394 (2), 447 (1), 463 (2), 500 (10 broad), 542 (1), 660 (2), 687 (2), 813 (0), 903 (2), 937 (2), 962 (1), 1045 (0), 1094 (6), 1125 (5), 1155 (4), 1445 (0), 1470 (2), 1570 (8 sh).

III. 3-(Diethylchlorisilyl)-tricyclo-(2,2,1,0^{2,6})-heptane.

270 (4 broad), 355 (2), 405 (2), 439 (2), 490 (0), 612 (0), 652 (0), 690 (1), 743 (0), 794 (7), 896 (2), 915 (3), 961 (6 broad), 998 (1), 1059 (10), 1092 (2), 1128 (8), 1149 (4), 1245 (4), 1293 (2), 1420 (2), 1452 (9v. broad).

IV. Mixture of 2-(ethyldichlorosilyl)-bicyclo-(2,2,1)-hept-5-ene and 3-(ethyldichlorosilyl)-tricyclo-(2,2,1,0^{2,6})-heptane.

173 (2 broad), 275 (5 broad), 327 (5 broad), 369 (2), 408 (7 sh), 442 (3), 461 (1), 485 (2), 500 (6), 685 (2), 801-807 (7), 891 (2), 905 (7), 932 (9), 958 (3 broad), 970 (2 broad), 1000 (1), 1017 (3), 1040 (2), 1068 (8), 1100 (9), 1132 (10), 1158 (8), 1251 (3), 1282 (2), 1300 (4), 1345 (1 broad), 1447 (4), 1462 (7), 1575 (5).

V. Mixture of 2-(propyldichlorosilyl)-bicyclo-(2,2,1)-hept-5-ene and 3-(propyldichlorosilyl)-tricyclo-(2,2,1,0^{2,6})-heptane.

152 (1), 182 (0), 250-264 (3v.broad), 316 (4), 448 (1), 463 (2), 493 (3), 511 (3), 572 (0), 640 (1), 790 (0), 808 (1 broad), 835 (0), 890 (0), 904 (3), 932 (5), 966 (1 broad), 995 (1), 1038 (6), 1064 (9), 1096 (10), 1128 (5), 1155 (1), 1184 (0), 1212 (1 broad), 1254 (0), 1289-1301 (4 broad), 1345 (1), 1407 (0), 1457 (6v.broad) 1570 (9 sh).

VI. Mixture of 2-(β-trichlorosilylethyl)-bicyclo-(2,2,1)-hept-5-ene and 2-vinyl-5(6)-trichlorosilylbicyclo-(2,2,1)-heptane.

180 (3), 188 (3), 232 (1 v. broad), 275 (8 broad), 325 (10), 369 (2), 398 (1), 433 (3), 455 (5), 468 (4), 497 (1), 520 (3 broad), 534 (0), 565 (1 broad), 587 (0), 768 (2), 800 (2), 830 (2), 845 (4), 902 (2), 914 (2), 932 (3 v. broad), 990 (2), 997 (2), 1020 (2), 1060 (2), 1095 (6), 1118 (5), 1200 (4), 1225 (1), 1268 (2), 1280 (1), 1300 (6), 1332 (0), 1420 (2), 1452 (6), 1564 (5), 1632 (6).

SUMMARY

1. The addition of a number of silicon hydrides to bicyclo-(2,2,1)-hept-5-ene, bicyclo-(2,2,1)-hepta-2,5-diene, 2-methyl- and 2-vinylbicyclo-(2,2,1)-hept-5-ene, and dicyclopentadiene has been carried out.

2. It has been shown that in the case of the reaction of ethyl- and n-propyldichlorosilanes with bicyclo-(2,2,1)-hepta-2,5-diene, a mixture of alkyldichlorosilyl-substituted bicyclo-(2,2,1)-hept-5-ene and tricyclo-$(2,2,1,0^{2,6})$-heptane is formed. The use of diethylchlorosilane in the same reaction leads to the production only of the substituted tricycloheptane.

3. Methylbicycloheptyl-, methylphenyl-, methylbenzyl-, and methyl-β-phenylethylsiloxane liquids have been synthesized and their viscosities and freezing points have been determined.

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ANOMALY IN THE COLOR OF
SOME MESO-PHENYLDIBENZOXANTHENE DERIVATIVES

M. V. Gorelik and L. S. Efros

The dehydrogenation of 9-phenyl-1,2; 7,8-dibenzoxanthene derivatives, in particular, of dibenzoxanthylium salts (I), yields compounds of general formula (II) [1], in due time attracting the attention of our laboratory as dyes for cellulose and animal fibers [2].

Designations for compounds (I)–(IV)	a	b	c	d	e	f	g	h	i
R	H	3-NH$_2$	4-NH$_2$	3-NO$_2$	4-NO$_2$	3-OCH$_3$	4-N(CH$_3$)$_2$	3-NHCOCH$_3$	4-NHCOCH$_3$
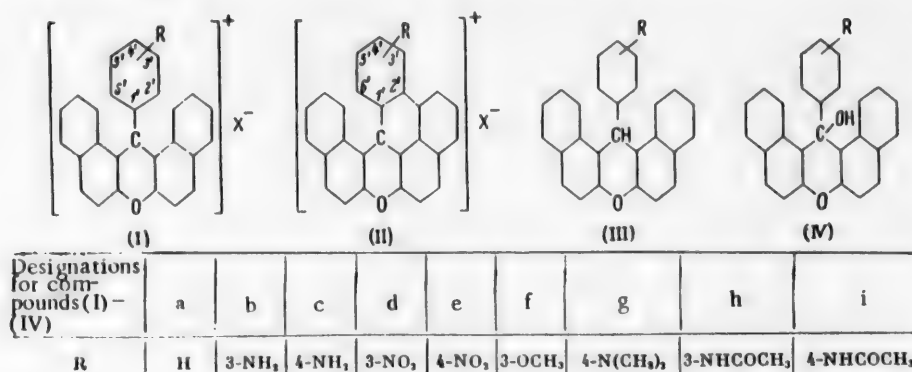
Transition from compounds (I) to compounds (II) causes an increase in the resistance of the salts to hydrolysis, the appearance of substantivity, and also a change in the color. An anomaly in the color was observed in the latter series, consisting in a deeper color of the compounds containing auxochrome groups in the meta-, and not in the para-position of the meso-phenyl ring [3, 4]. Thus, for example, compound (IIb), containing a m-amino group, is colored green, while compound (IIc), containing a p-amino group, is colored red. It seemed of interest to make a somewhat more detailed study of this phenomenon.

For this purpose we condensed β-naphthol with the appropriate aldehydes and obtained meso-phenyldibenzoxanthene (IIIa) [5] and its derivatives, containing in the meso-phenyl ring the nitro (IIId, IIIe) [6, 7], methoxy (IIIf) [3], and p-dimethylamino (IIIg) [8] groups. The acetamido compounds (IIIh, IIIi) were synthesized by the reduction of nitro compounds (IIId) and (IIIe) with zinc in acetic acid [6, 7], while the corresponding xanthenols (IVa, d-i) were obtained by the oxidation of compounds (IIIa, d-i) with either lead or manganese dioxide. Contrary to the literature data regarding the stability of 9-(4'-dimethylaminophenyl)-1,2; 7,8-dibenzoxanthene (IIIg) [8] toward oxidizing agents, the conversion of the compound to xanthenol (IVg) did not encounter any special difficulties. Xanthenols (IVb, c), containing free amino groups, were obtained by the hydrolysis of the acetamido compounds (IVh, i) in hydrochloric acid medium.

The dehydro derivatives (II) were prepared by methods described in the literature: dyes (IIa, b, c) were obtained by the respective fusion of compounds (IVa), (IIIb) and (IVc) with aluminum chloride [1]; compounds (IIf), (IId) [3] and (IIe) were obtained by the irradiation of solutions of the corresponding salts (I) with simultaneous bubbling in of air; the p-dimethylamino derivative (IIg) was obtained in small yield by both this and a different method. In the last case, in the photochemical dehydrogenation, we isolated besides (IIg) also an unknown green byproduct. The photochemical dehydrogenation of acetamido compounds (Ih, i) in the presence of mineral acid led to the formation of dyes (IIb) and (IIc), containing free amino groups. We obtained the same violet dye when (IIb) and (IIc) were deaminated, which spectrally proved to be identical with (IIa)—the dehydrogenation product of the unsubstituted
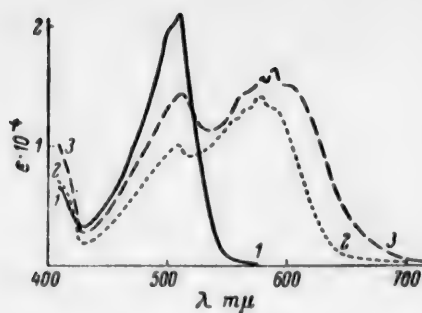
Fig. 1. Absorption spectra of nitrobenzene solutions of dibenzoxanthylium salts (I). 1) Compound (Ia), $X = ClO_4^-$; 2) compound (Ic), $X = Cl^-$; 3) compound (Ig), $X = ClO_4^-$.
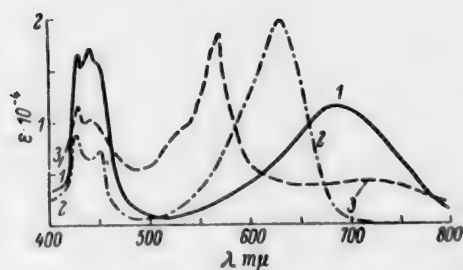
Fig. 2. Absorption spectra of nitrobenzene solutions of perchlorates of dehydro compounds (II). 1) Compound (IIb); 2) compound (IIf); 3) compound (IId).
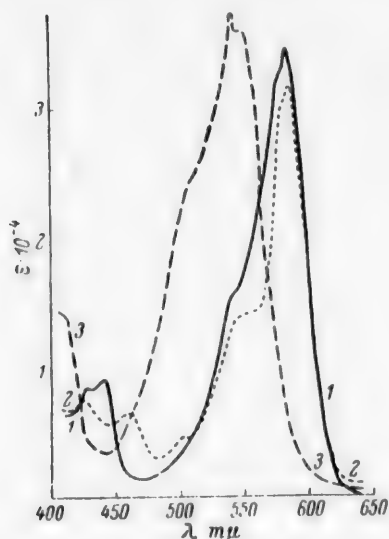
Fig. 3. Absorption spectra of nitrobenzene solutions of perchlorates of dehydro compounds (II). 1) Compound (IIa); 2) compound (IIe); 3) compound (IIc).

meso-phenyldibenzoxanthenol (IVa). Consequently, the dehydro derivatives (II) have the same carbon skeleton, and their different color is due to the influence of the substituents in the meso-phenyl ring.

For the spectral studies we used nitrobenzene solutions of either the perchlorates or chlorides of the dibenzoxanthylium salts (I) and corresponding dehydro derivatives (II).

In the spectra of the undehydrogenated compounds (I) (Fig. 1) the maximum, characteristic for the system of bonds in meso-phenyldibenzoxanthylium, is located in the interval 506-514 mμ independent of the character of the substituent (R = 3-NH$_2$, λ_{max} 506 mμ; Ia, c-i, λ_{max} 511-514 mμ). The presence of a para-auxochrome in the meso-phenyl ring of compounds (I) is responsible for the appearance of an additional absorption band in the long-wave region. At the same time, the basicity of the xanthenols also increases. If salts (Ia) or (Ib) hydrolyze rapidly in the presence of traces of water, then salt (Ig) gives in water intensely colored solutions, which decolorize only gradually as the result of hydrolysis.

The influence of substituents in the meso-phenyl nucleus of the dehydro derivatives is manifested in a different manner. The unsubstituted dehydro compound (IIa) is characterized by two absorption bands: one of lower intensity at around 440 mμ and one of greater intensity at 582 mμ. The introduction of meta-substituents into the meso-phenyl ring reduces the intensity of the principal maximum and shifts it in the case of electron-acceptor groups toward shorter wavelengths (R = 3-NO$_2$, λ_{max} 750 mμ), while in the case of electron-donor groups the maximum is shifted toward longer wavelengths (R = 3-NH, λ_{max} 685 mμ; R = 3-OCH$_3$, λ_{max} 629 mμ; R = 3-NHCOCH$_3$, λ_{max} 592 mμ). The first absorption band is not shifted, although its intensity changes (Fig. 2). The introduction of analogous substitutents in the para-position of the meso-phenyl ring of the dehydro derivatives (II) produces the opposite effect: A slight bathochromic shift is observed in the spectrum of the para-nitro compound (IIe)(λ_{max} 585 mμ), while a hypsochromic shift of the principal maximum is observed in the spectra of the p-amino and p-dimethylamino derivatives (λ_{max} 540, 547 and 530, 539 mμ, respectively), and also an increase in the integral absorption and a disappearance of the maximum at around 440 mμ (Fig. 3).

As a result, a bathochromic effect when dibenzoxanthylium salts (I) are dehydrogenated to (II) derivatives, observed by Dilthey and co-workers [3], occurs only in compounds not containing para-auxochromes. Closure of the new ring in the latter compounds is accompanied by a hypsochromic shift and an increase in the intensity of absorption.

Interpretation of the color of the given group of meso-phenyldibenzoxanthene derivatives should be the subject of further study.

EXPERIMENTAL

9-(3'-Acetamidophenyl)-1,2; 7,8-dibenzoxanthenol (IVh). To a boiling solution of 3.5 g of compound (IIIh), m.p. 245-246° (from the literature [6]; m.p. 246-247°), in 250 ml of glacial acetic acid was gradually added 7.5 g of a 45% paste of freshly prepared lead dioxide. The obtained dark-colored solution was filtered and diluted with hot water. After cooling, the obtained precipitate was filtered, recrystallized from aqueous acetone, and then from aqueous pyridine. The compound was obtained as colorless silky needles with m.p. 290° (decomp.), difficultly soluble in ether and chloroform, and readily soluble in alcohol, acetone and glacial acetic acid. A red solution is formed in concentrated sulfuric acid, from which the unchanged substance deposits on dilution with water.

Found %: C 80.52; H 4.90; N 3.13. $C_{29}H_{31}O_3N$. Calculated %: C 80.71; H 4.87; N 3.23.

The perchlorate (Ih, X = ClO_4^-) separates out when perchloric acid is added to a solution of the xanthenol in a small amount of acetic acid. The compound was obtained as orange-red hexahedral plates with a green metallic luster (from glacial acetic acid), m.p. 259-260° (decomp.). The compound is readily soluble in acetone, nitrobenzene and acetic anhydride, forming yellow solutions that are decolorized in the presence of water or alcohol.

9-(3'-Aminophenyl)-1,2; 7,8-dibenzoxanthenol (IVb). A solution of 0.9 g of compound (IVh) in 50 ml of 25% hydrochloric acid solution was refluxed for 5 hr, after which it was poured into water. The obtained precipitate was filtered and then recrystallized from aqueous acetone and aqueous pyridine. Fine colorless needles with m.p. 291-292°; the mixed melting point with the starting acetyl derivatives (IVh) was 268°. The compound diazotizes in 50% aqueous acetone, and it also couples, forming a yellow solution with alkaline β-naphthol solution, and an orange-red solution with the sodium salt of 2-naphthol-3,6-disulfonic acid.

The substance is readily soluble in benzene, chloroform and glacial acetic acid, soluble in ether and dichloroethane, difficultly soluble in alcohol, and practically insoluble in carbon tetrachloride.

Found %: C 82.97; H 5.05; N 3.56. $C_{27}H_{19}O_2N$. Calculated %: C 83.30; H 4.89; N 3.60.

Perchlorate (Ib, X = ClO_4^-). Two drops of 30% perchloric acid solution was added to a solution of 0.1 g of compound (IVb) in 15 ml of 25% hydrochloric acid. After some time the crystals of the perchlorate deposited and were filtered. The compound was obtained as brownish-red diamond-shaped plates with a green metallic luster; it decomposed gradually, without melting, when heated to 330°. Orange solutions of the substance in acetic acid, nitrobenzene or acetone are decolorized rapidly when either water or alcohol is added.

9-(4'-Aminophenyl)-1,2;7,8-dibenzoxanthenol (IVc). A solution of 0.6 g of compound (IVi), m.p. 274° (decomp.), (from the literature [7] m.p. 270°), in 15 ml of 25% hydrochloric acid was refluxed for 5 hr, during which time the color of the initially pale red solution became much more intense. After cooling, the obtained coarse dark-red plates, having a greenish metallic luster, of the chloride were filtered and dried in vacuo.

The chloride (Ic, X = Cl^-) does not melt when heated to 330°, is soluble in acetone, dichloroethane, nitrobenzene and glacial acetic acid with an intense cherry-red color, and is insoluble in benzine, ether and carbon tetrachloride. The solutions are decolorized in the presence of either water or alcohol; when a solution of the compound in acetic anhydride is boiled the cherry-red color changes to yellow (acetylation). In water the compound, not dissolving, goes to the xanthenol (IVc).

The precipitate, obtained when water was added to a hot acetone solution of (Ic), was recrystallized from aqueous acetone and then from aqueous pyridine. The compound was obtained as yellow prisms that darkened at ~285°, and at 288° decomposed with a stormy evolution of gases. The substance has the same solubility properties as (IVb); after diazotization in 50% aqueous acetone solution it gives a red color with alkaline β-naphthol solution.

Found %: C 82.18; H 4.89; N 3.72. $C_{27}H_{19}O_2N$. Calculated %: C 83.30; H 4.89; N 3.60.

9-(4'-Dimethylaminophenyl)-1,2;7,8-dibenzocanthenol (IVg). To a solution of 5 g of compound (IIIg), m.p. 212° [from the literature [8]; m.p. 214-215° (corr.)], in a mixture of 300 ml of glacial acetic acid and 50 ml of conc. hydrochloric acid was added, at 45°, 3 g of finely pulverized manganese dioxide. After stirring for 10 min at the same temperature the dark-colored reaction mass was filtered, and the filtrate was cooled and diluted with

300 ml of ether. After 15-20 hr the obtained dark-red prisms, having a green metallic luster, were filtered and washed with ether. The yield of the chloride (Ig, X = Cl⁻) was 3.8 g. The substance is readily soluble in water and alcohol, forming permanganate-red solutions that gradually decolorize.

Water was added to a solution of 2 g of chloride (Ig) in 40 ml of acetone to incipient precipitation of xanthenol (IVg), which after cooling of the mixture was filtered and dried. Yield 1.65 g, m.p. 231-232°. After recrystallization from aqueous acetone and aqueous pyridine the compound was obtained as colorless needles with m.p. 247°, soluble in alcohol, dichloroethane, ether, and carbon tetrachloride. The solutions in sulfuric and hydrochloric acids have a golden-yellow color, while an acetic acid solution of the compound gradually assumes an intense permanganate-red color.

Found %: C 83.82; H 5.25; N 3.53. $C_{29}H_{23}O_2N$. Calculated %: C 83.47; H 5.52; N 3.36.

Perchlorate (Ig, X = ClO_4^-). The addition of perchloric acid to a solution of 0.5 g of the xanthenol in 30 ml of glacial acetic acid resulted in the immediate deposition of golden-yellow plates, which were filtered and washed with acetic acid and then with ether; m.p. 266° (decomp.). The substance is soluble in chlorobenzene, dichloroethane or acetic anhydride, with a permanganate-red color. The compound is insoluble in water, ether, and benzine. When the compound is dissolved in pyridine and alcohol the appearing color disappears rapidly.

Found %: Cl 7.27. $C_{20}H_{22}O_5NCl$. Calculated $^{\sigma}$: Cl 7.1.

Dehydrogenation of 9-(4'-nitrophenyl)-1,2;7,8-dibenzoxanthenol (IVe). With a constant bubbling in of air, a refluxing solution of 0.4 g of compound (IVe) in a mixture of 100 ml of glacial acetic acid, 30 ml of acetone and 3 ml of perchloric acid was exposed for 4 hr to the illumination from a 750-watt incandescent lamp placed at a distance of 15 cm from the flask with solution. During the time of illumination the color of the solution changed from an orange to a violet-red, and a precipitate began to deposit, which after cooling of the mixture was filtered and washed with acetic acid and then with alcohol. The yield of perchlorate (IIe) was 0.14 g. The compound was obtained as brown prisms with a golden luster, readily soluble with a violet-red color and a yellow fluorescence in nitrobenzene, acetic anhydride and pyridine, and less readily soluble in acetic acid, acetone and dichloroethane.

Found %: C 64.84; H 2.67; N 2.71. $C_{27}H_{14}O_7NCl$. Calculated %: C 65.24; H 2.82; N 2.82.

Dehydrogenation of 9-(4'-dimethylaminophenyl)-1,2;7,8-dibenzoxanthenol (IVg). a) To a fused mixture of 5 g of anhydrous aluminum chloride and 1 g of sodium chloride at 130° was added 1 g of chloride (Ig). The mass was stirred for 6 hr at 140-150°, after which it was poured into 100 ml of water. The violet solution was boiled, filtered, and the precipitate was treated several times with boiling water. The filtrates were combined, conc. hydrochloric acid was added, and the obtained tarry precipitate was separated. The dye is readily soluble in water and dyes both cotton and wool a violet-red color. For analysis, the product was purified by repeated precipitation from water with hydrochloric acid, after which it was converted to the perchlorate and dried at 120°.

Perchlorate (IIg) is soluble with a violet color in acetic anhydride and nitrobenzene, and is less readily soluble in glacial acetic acid and in pyridine. The absorption spectrum in nitrobenzene is λ_{max} 530, $\varepsilon \cdot 10^{-4}$ 2.3; λ_{max} 539, $\varepsilon \cdot 10^{-4}$ 2.4; inflection λ 600, $\varepsilon \cdot 10^{-4}$ 1.6.

Found %: N 2.93; Cl 7.31. $C_{29}H_{20}O_5NCl$. Calculated %: N 2.81; Cl 7.13.

b) In the same manner as compound (IVe), 0.4 g of xanthenol (IVg) was subjected to photochemical dehydrogenation for 16 hr. After 4 hr a precipitate began to deposit from the permanganate-red solution, after 8 hr the color of the solution changed to blue, and after 16 hr it changed to green. When the precipitate was filtered we obtained 50 mg of perchlorate (IIg) crystals, identical in their properties and absorption spectrum to the compound obtained in "a".

The filtrate was evaporated in vacuo to dryness, the residue was dissolved in acetone, and the solution was chromatographed on aluminum oxide. Besides some orange-red impurities, we isolated a small amount of tarry substance, which was readily soluble in acetone, nitrobenzene and pyridine, with an emerald-green color (λ_{max} in nitrobenzene, 490 and 640 mμ); a green solution with a dark-red fluorescence is formed in dichloroethane, while a greenish-blue solution is obtained in acetic acid. In concentrated mineral acids the color of the substance changes to a purple-red, which returns to a green color on dilution.

Dehydrogenation of 9-acetamidophenyl-1,2;7,8-dibenzocanthenols (IVh) and (IVi). a) Similar to xanthenol (IVe), 0.4 g of either xanthenol (IVh) or (IVi) was subjected to photochemical dehydrogenation for 6 hr. In the case of compound (IVh) we isolated 50 mg of crystalline substance, which dissolved with a green color in alcohol, nitrobenzene or hot acetone, and in acetic anhydride with a blue color and a red fluorescence. In concentrated mineral acids the product gives violet-red solutions, from which green flocs deposit on dilution. Spectrally the compound is identical with the perchlorate of dye (IIb), obtained by the fusion of xanthene (IIIb) with aluminum chloride [1, 3] (Curve 1, Fig. 2).

In the case of (IVi) we isolated 55 mg of a dark-red powder, soluble in hot water, nitrobenzene or acetic anhydride with a purple-red color. Spectrally the substance is identical with the perchlorate of dye (IIc), obtained by the fusion of xanthenol (IVc) with aluminum chloride [1, 3] (Curve 3, Fig. 3).

Deamination of green (IIb, X = Cl⁻) and red (IIc, X = Cl⁻) dyes. a) To a solution of 50 mg of the chloride of either dye (IIb) or (IIc), prepared by fusion with aluminum chloride [1, 3], in 100 ml of alcohol was added 25 ml of conc. sulfuric acid and then 3 ml of 20% sodium nitrite solution was added at 20°. The obtained suspension was stirred for 40 min, heated for 10 min at 50°, cooled, and filtered. The precipitate was dissolved in hot water, and the obtained dye was precipitated from the ink-blue solution with conc. hydrochloric acid, separated, and converted to the perchlorate. Yield 25-30 mg. The substance does not contain nitrogen, its solutions in nitrobenzene, alcohol and acetic anhydride exhibit a reddish-violet color and an intense red fluorescence, and its absorption spectrum is identical with the spectrum of the perchlorate of (IIa), prepared by the dehydrogenation of xanthenol (IVa) [1] (Curve 1, Fig. 3).

b) To a solution of 0.1 g of green dye (IIb) in 45 ml of water were added 50 ml of alcohol and 5 ml of 0.5 N sodium nitrite solution, and then 10 ml of conc. sulfuric acid was added at 20-30°. The solution turned red and a precipitate deposited, which was filtered and purified by precipitation from water with hydrochloric acid. The same violet dye as in the case of "a" was obtained, identical in its properties and spectral characteristics with compound (IIa, X = ClO₄⁻).

Spectroscopy. Solutions of the compounds in nitrobenzene were used for the spectroscopic measurements. An SF-4 spectrophotometer was used to make the measurements, which were made at 5 mμ intervals, while the positions of the maxima were defined more accurately. In view of the poor stability of the solutions of the (I) salts during illumination we took the necessary precautions. In measuring the spectra of the (I) salts we observed in a number of cases a 15-20% reduction in the intensity of absorption without a noticeable shift of the maximum. The solution of the m-amino derivative (Ib) was the least stable, while the solutions of the compounds with the p-auxochromes, (Ic) and (Ig), were the most stable.

SUMMARY

1. The dehydrogenation products of meso-phenyl-1,2;7,8-dibenzoxanthene derivatives, containing different substituents in the meso-phenyl ring, have the same carbon skeleton.

2. In the series of dibenzoxanthylium salts, the introduction of auxochrome groups in the p-position of the meso-phenyl ring leads to a sharp deepening of the color, while when introduced in the m-position the effect on the color is slight, whereas in the series representing the dehydrogenation products of the dibenzoxanthylium salts (II) the presence of electron-donor groups in the p-position causes a hypsochromic effect, while if the electron-donor groups are in the m-position a substantial bathochromic effect results; electron-acceptor groups show the opposite effect.

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IMIDAZOLE DERIVATIVES

XXIV. SYNTHESIS AND OXIDATION OF 5-CHLORO-6-METHOXY-2-BENZIMIDAZOLINONE

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In a previous paper [1] we mentioned the case with which the 5,6-dimethoxyl derivatives of 2-benzimida-zolinone are converted to the 5,6-dioxo compounds when subjected to the action of oxidizing agents. It proved that 5-methoxy-6-chloro-1,3-dimethyl-2-benzimidazoline (IV) is also capable of similar oxidative cleavage.

Proposing to obtain this compound from the previously unknown 1,2-diamino-4-chloro-5-methoxybenzene (II), we synthesized the latter by the reduction of 2-nitro-4-methoxy-5-chloroaniline (I) [2]; the diamine (II) was characterized as the piaselenole derivative (VII).
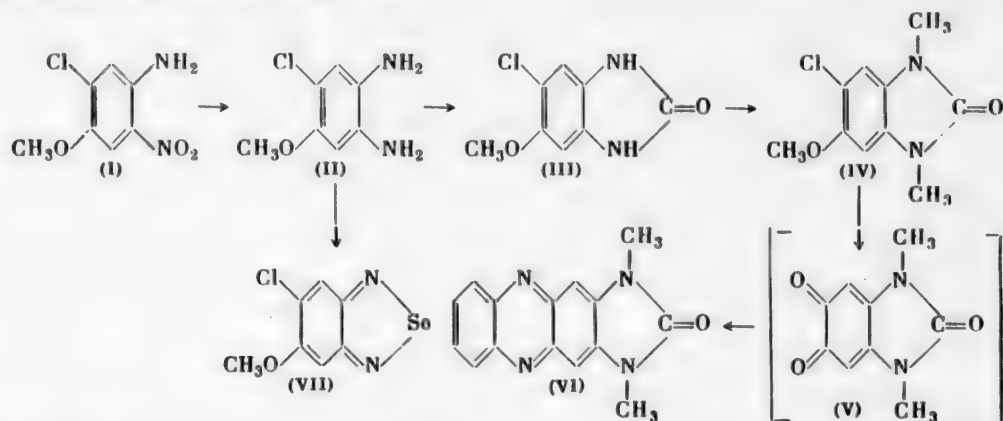
The fusion of the diamine base (II) with urea gave us 5-chloro-6-methoxy-2-benzimidazolinone (III), which when treated with dimethyl sulfate in alkaline solution led to the isolation of the N,N'-dimethyl derivative (IV). This compound was then subjected to the action of various oxidizing agents.

In contrast to 5,6-dimethoxy-1,3-dimethyl-2-benzimidazolinone, easily cleaved by nitrous acid or $FeCl_3$ to the quinone (V), we established that compound (IV) is not decomposed by these oxidizing agents. Only Ce^{+4} salts and dilute nitric acid led to the formation of quinone (V), identified as the azine (VI), described previously [1]. However, the oxidation with nitric acid went only when the reaction mixture was refluxed, and was accompanied by the formation of unidentified nitro compounds, which was not observed in the case of the 5,6-dimethoxy derivatives, the oxidation of which went rapidly even in the cold.

Here it is important to mention that despite the presence in (IV) of a free position ortho to the methoxyl group, the oxidation goes with a displacement of the chlorine atom and the formation of the 5,6-quinone. The reason for this is because 2-benzimidazolinone derivatives tend to form compounds with a quinoid structure at the 5 and 6 positions.

In synthesizing 5-chloro-6-methoxy-2-benzimidazolinone (III) we encountered an unexpected reaction course when diamine (II) was condensed with urea. When the hydrochloride of diamine (II), isolated directly from the catalytic reduction of nitroaniline (I) in dioxane, was fused with urea we obtained 2,3-imidazolono-7-chloro-8-methoxyphenazine (IX), which was characterized as the N,N'-dimethyl derivative (X). The latter in turn was

identified by the absorption spectrum of its solution in isopropyl alcohol with the phenazine obtained by the condensation of diamine (II) with quinone (V), described in detail earlier [3].

It might be thought that the first stage of this curious condensation is nucleophilic attack by the amino group of diamine (IIa) on the chlorine-bearing carbon atom of the second diamine molecule (IIb). The electrophilicity of this carbon atom is due not only to the inductive effect of the chlorine atom, but also to the influence exerted by the positive charge of the salt-forming amino group. Apparently, both of these factors have equal importance, since the free base 1,2-diamino-4-chloro-5-methoxybenzene, the same as the hydrochloride of 1,2-diamino-4,5-dimethoxybenzene [3], both form normal reaction products— the benzimidazolinone derivatives— when fused with urea.
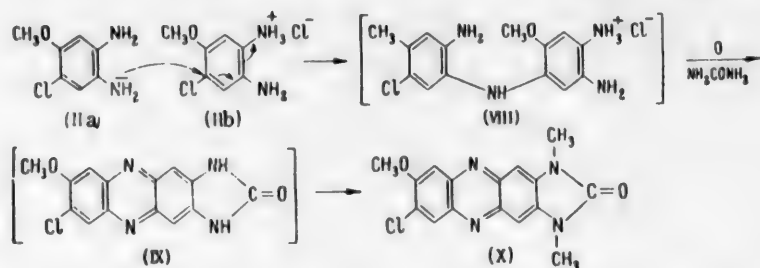
The lower reactivity of the chlorine atom in the intermediate product (VIII), preventing the formation of polycyclic high-molecular compounds, is apparently due to the lower basicity of the amino group in the p-position to the chlorine atom. The latter is caused not only by the influence exerted by the diphenylamine system, but also because of steric hindrance.

The formation of the phenazine derivative (IX) is due to the oxidation and condensation of product (VIII) with urea. In the present case the role of oxidizing agent is fulfilled by peroxide compounds of dioxane, present as impurities in the diamine (II). However, the oxidation can also take place as the result of atmospheric oxygen: The pure hydrochloride of diamine (II) also gives phenazine (IX) when fused with urea, but in smaller yield.

In our case the phenazine synthesis [4] is accompanied by displacement of the methoxyl group when the o-position is open. The elimination of substituents in the phenazine condensation was observed only for the case of 1,2-diaminonaphthalene, containing an acetamido group in the 4-position [5]. Such a reaction course was due not only to the absence of positions suitable for substitution, but chiefly because of the exceptional stability of the 1,2-naphthoquinone structure.

Apparently, an analogous factor also played a decisive role in the case of forming compound (IX), since the energetically favorable structure of the 5,6-dioxo-2-benzimidazolinone is characterized by a high stability [1, 3].

EXPERIMENTAL

1,2-Diamino-4-chloro-5-methoxybenzene (II). This compound was obtained both by the catalytic hydrogenation of 2-nitro-4-methoxy-5-chloroaniline* (I) [see the synthesis of azine (X) below], and by reduction of the same compound with hydrosulfite. Stirring with a rod, 1 g of nitroaniline (I) and sodium hydrosulfite were added simultaneously, in small portions, to 20 ml of gently boiling water until the solution decolorized (about 3 g of sodium hydrosulfite). The hot solution was filtered rapidly, and the filtrate was cooled to 0°. The crystalline precipitate was filtered and dried in vacuo. We obtained 0.35 g of diamine (II). Colorless needles, m.p. 126.5° (decomp.) (from toluene). The substance is soluble in water, readily soluble in alcohol and chloroform, and more difficultly soluble in ether. The hydrochloride is salted out from aqueous solution using conc. hydrochloric acid.

Found %: N 16.06, 16.08; Cl 20.94. $C_7H_9ON_2Cl$. Calculated %: N 16.27; Cl 20.68.

5-Methoxy-6-chloroselenodiazole (VII) was obtained by pouring together a water solution of the free diamine (II) and a solution of selenious acid. Slender needles with a yellow tinge, m.p. 202° (from alcohol).

Found %: N 11.36, 11.54; Cl 14.50, 14.81. $C_7H_5ON_2Cl$. Calculated %: N 11.32; Cl 14.35.

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*Synthesized in collaboration with E. N. Glibin.

5-Methoxy-6-chloro-2-benzimidazolinone (III) was obtained by the fusion of the free diamine (II) with urea at 200°. The substance was recrystallized from aqueous acetic acid and then from dioxane, m.p. 311°, fine colorless needles. Yield 75%.

Found %: N 14.24, 14.11; Cl 18.01, 17.51. $C_8H_7O_2N_2Cl$. Calculated %: N 14.15; Cl 17.88.

5-Methoxy-6-chloro-1,3-dimethyl-2-benzimidazolinone (IV). To a solution of 2.7 g of compound (III) in 25 ml of 6% NaOH was added at 90°, in drops, 2.6 ml of dimethyl sulfate, then 1 g of NaOH was added, and the whole was refluxed for 1 hr with stirring. The reaction mixture on cooling deposited the dimethyl derivative (IV), which was filtered, while the mother liquor was neutralized with acid, and the obtained precipitate was dried and remethylated. Yield 2.5 g (82.5%), m.p. 171.5° (from alcohol). The substance is soluble in organic solvents, and is difficultly soluble in water.

Found %: N 12.29, 12.54; Cl 15.68, 15.39. $C_{10}H_{11}O_2N_2Cl$. Calculated %: N 12.35; Cl 15.67.

2,3-(1',3'-Dimethylimidazolono)-7-chloro-8-methoxyphenazine (X). A solution of 30 g of nitroaniline (I) in 150 ml of freshly distilled dioxane was loaded into a 600-ml autoclave and hydrogenated at 100 atm and room temperature for 24 hr in the presence of Raney nickel [6]. The catalyst was filtered and the slightly colored dioxane solution was diluted with 1 liter of ether, after which the diamine was precipitated as the hydrochloride by passing a stream of dry HCl into the solution. The amine salt was dried slightly in an oven with air circulation (60°), and then it was fused at 200° (in the bath) with 40 g of urea for 20 min. The dark melt was precipitated from 5% NaOH solution with hydrochloric acid, the azine precipitate was filtered, dried (26 g), and then methylated in the same manner as described for the synthesis of compound (IV). The dimethyl derivative (X) was chromatographed on aluminum oxide from chloroform solution, and then it was recrystallized from acetic acid. We obtained 15 g of bright yellow, finely crystalline powder, not melting up to 320°. The solution of the compound in conc. H_2SO_4 has an intense crimson color.

Found %: N 17.10, 17.08; Cl 10.62, 10.95. $C_{16}H_{13}O_2N_4Cl$. Calculated %: N 17.05; Cl 10.80.

The condensation of 5,6-dioxo-1,3-dimethyl-2-benzimidazolinone (V) [3] with diamine (II) in acetic acid gave 2,3-(1',3'-dimethylimidazolono)-7-chloro-8-methoxyphenazine, the spectrum of which in isopropyl alcohol coincided with the spectrum of the azine described above.

Oxidation of 5-methoxy-6-chloro-1,3-dimethyl-2-benzimidazolinone (IV). a) Using tetravalent cerium salt. A freshly prepared alcohol solution of 12 g of ammonium cerium sulfate was added with stirring to a solution of 1 g of compound (IV) in 60 ml of alcohol. After adding all of the oxidizing agent, the colored solution was poured into 500 ml of water and then extracted with chloroform until the extract was colorless. The extract was dried over $MgSO_4$, then evaporated in vacuo to dryness, and the residue was dissolved in 5 ml of acetic acid containing 0.6 g of o-phenylenediamine. After boiling for 3 min the reaction mass was filtered, and the precipitate was recrystallized from acetic acid. We obtained 0.3 g of the azine as fine bright-yellow needles. The substance does not contain halogen or methoxyl groups, and is soluble in conc. H_2SO_4 with a red color. The spectrum of an alcohol solution of 2,3-(1',3'-dimethylimidazolono)phenazine (VI) coincided with the spectrum of the same substance described earlier [1].

Found %: N 21.65, 21.50. $C_{15}H_{12}ON_4$. Calculated %: N 21.21.

b) Using nitric acid. Compound (IV) (0.5 g) was heated under reflux for 10 min in a solution of 6 ml of HNO_3 (d 1.34) in 50 ml of water. After cooling, the dark red solution was extracted with chloroform (5 × 50 ml), in which connection only a portion of the precipitated nitro compounds went into the extract. After drying over $MgSO_4$, the chloroform extract was evaporated in vacuo, and the residue was condensed with 0.3 g of o-phenylenediamine in 4 ml of acetic acid. The precipitate obtained on cooling was recrystallized twice from acetic acid. We obtained 0.08 g of the azine as bright yellow needles. The substance does not contain halogen or methoxyl groups, is soluble in conc. H_2SO_4 with a red color, and the spectrum of an alcohol solution of the thus obtained 2,3-(1',3'-dimethylimidazolono)phenazine (VI) coincided with the spectrum of the same substance described earlier [1].

Found %: N 21.33, 21.40. $C_{15}H_{12}ON_4$. Calculated %: N 21.21.

SUMMARY

1. It was shown that 5-methoxy-6-chloro-1,3-dimethyl-2-benzimidazolinone is oxidized by Ce^{+4} salts and by dilute nitric acid to the 5,6-dioxo compound, identified as the phenazine.

2. The formation of 2,3-imidazolono-7-chloro-8-methoxyphenazine was confirmed when the hydrochloride of 1,2-diamino-4-chloro-5-methoxybenzene was fused with urea.

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DYES WITH ANTIPYRINE NUCLEI

VII. INFLUENCE OF SUBSTITUENTS ON THE COLOR AND ACID-BASE PROPERTIES OF DYES

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The introduction of the dimethylamino group in the p-position to the central carbon atom in the dye Antipyrine Orange leads to a substantial deepening of the color [1]. The amino and diethylamino groups should also exert an analogous effect, in which connection the bathochromic effect of the amino group, as follows from the modern concepts regarding the relationship between structure and color [2], should be less, and that of the diethylamino group should be greater than the effect of the dimethylamino group. Having synthesized the corresponding dyes, we made a study of both the absorption spectra and the acid-base properties of these compounds (Table 1).

TABLE 1. Values of λ_{max} and Hydrolysis Constants of Dyes with Antipyrine Nuclei

Compound No.	x	λ_{max} mμ	K_H
I	$N(C_2H_5)_2$	560	$1.0 \cdot 10^{-11}$
II	$N(CH_3)_2$	550	$3.0 \cdot 10^{-11}$
III	NH_2	520	$2.5 \cdot 10^{-10}$
IV	H	480	$2.5 \cdot 10^{-7}$
V	NO_2	500	$1.8 \cdot 10^{-5}$

As can be seen from an examination of Table 1, with increase in the nucleophilic character of the amino group the color of the dyes deepens, while the stability to hydrolysis increases. It should be mentioned that when a nitro group is introduced in the p-position to the central atom in Antipyrine Orange, as had been shown in a previous communication, the position of λ_{max} is shifted by 20 mμ toward longer wavelengths, while the hydrolysis constant increases by approximately 70 times [3]. As a result, in the class of antipyrine dyes a deepening of the color is not always accompanied by an increase in the stability to hydrolysis.
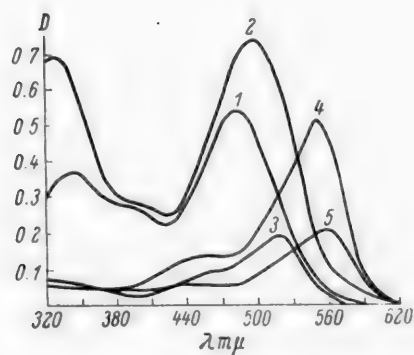
Absorption spectra of dyes with antipyrine nuclei. The numbers in the figure correspond to the numbers in Table 1.
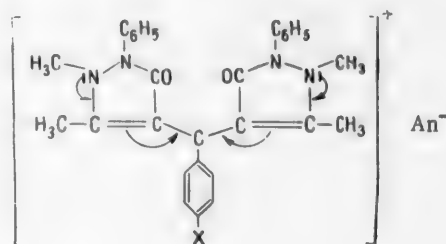
EXPERIMENTAL

Diantipyrinyl-p-diethylaminophenylmethane. Dihydrochloride. A solution of 3.54 g of p-diethylaminobenzaldehyde in 5 ml of hydrochloric acid (d 1.18) was added to a solution of 7.52 g of antipyrine in 10 ml of hydrochloric acid (d 1.18), followed by the addition after 15 min of 10 ml of water. The next day the precipitate was filtered and then recrystallized from 5% hydrochloric acid. The obtained salt was dried at a temperature not exceeding 60°. The yield was quantitative. The compound begins to decompose in the capillary at 162°.

Found %: HCl 12.24, 12.60. $C_{33}H_{37}O_2N_5 \cdot 2HCl$. Calculated %: HCl 12.00.

Free base. Two grams of the dihydrochloride was dissolved in 50 ml of water with heating, and the obtained solution was treated with NaOH solution until alkaline. After recrystallization from a mixture of acetone and benzine the free base had m.p. 183-184°.

Found %: C 74.18; H 6.52; N 13.17. $C_{33}H_{37}O_2N_5$. Calculated %: C 74.00; H 6.92; N 13.08.

Dipicrate, m.p. 193° (from alcohol).

Found %: N 15.67. $C_{33}H_{37}O_2N_5 \cdot 2C_6H_3O_7N_3$. Calculated %: N 15.50.

Diantipyrinyl-p-aminophenylmethane. Dihydrochloride. Freshly prepared p-aminobenzaldehyde (0.61 g) was added to a solution of 1.88 g of antipyrine in 5 ml of hydrochloric acid (d 1.18). After 15 min 5 ml of water was added. After five days the thick mass was stirred with 75 ml of 5% hydrochloric acid and heated. Here the main portion of the precipitate dissolved. The hot solution was filtered. The precipitate obtained on cooling the filtrate was filtered, washed with 5 ml of 5% hydrochloric acid, and dried at 60-70°. The compound was obtained as a finely yellow powder, m.p. 222-224° (decomp.).

Found %: HCl 13.32. $C_{29}H_{29}O_2N_5 \cdot 2HCl$. Calculated %: HCl 13.20.

Free base. The free base was isolated from the hydrochloride in the same manner as described above for diantipyrinyl-p-diethylaminophenylmethane. M.p. 230-231° (from a mixture of benzene and benzine).

Found %: C 72.46, 72.98; H 6.48, 6.30, N 14.52. $C_{29}H_{29}O_2N_5$. Calculated %: C 72.62; H 6.09; N 14.60.

Dipicrate, m.p. 180-181° (from alcohol).

Found %: N 16.48, 16.72. $C_{29}H_{29}O_2N_5 \cdot 2C_6H_3O_7N_3$. Calculated %: N 16.43.

Diantipyrinyl-p-diethylaminophenylcarbinol. A solution of 5.0 g of diantipyrinyl-p-diethylaminophenylmethane dihydrochloride in 100 ml of 10% ferric chloride solution was heated for 1.5 hr on the boiling water bath. With vigorous stirring, 5% NaOH solution was added in drops to the cooled solution until the mixed precipitate of ferrous

TABLE 2. Effect of pH on the Color Intensity of Dye Solutions at 21 ± 1°

Name of compound	pH	D	α	rK_a
Diantipyrinyl-p-aminophenylcarbinol, 0.0050 g, V 0.75 ml	4.23	0.232	1	
	9.49	0.135	0.58	4.19
	9.81	0.080	0.35	4.34
Diantipyrinyl-p-aminophenylcarbinol picrate, 0.773 g, V 0.15 m	4.23	0.511	1	—
	9.49	0.301	0.59	4.35
	9.81	0.184	0.36	4.34
Diantipyrinyl-p-dimethylaminophenylcarbinol [1], 0.0520 g, V 0.15 ml	4.00	0.678	1	—
	10.04	0.518	0.76	3.49
	10.29	0.386	0.57	3.62
	10.32	0.403	0.59	3.55
	10.58	0.323	0.48	3.48
Dye Antipyrine Red**	4.00	0.317	1	—
	10.04	0.260	0.82	3.33
	10.29	0.195	0.62	3.53
	10.32	0.196	0.62	3.50
	10.58	0.144	0.46	3.52
Diantipyrinyl-p-diethylaminophenylcarbinol, 0.0055 g, V 0.75 ml	4.00	0.325	1	—
	10.29	0.276	0.85	2.99
	10.58	0.246	0.76	2.96
Diantipyrinyl-p-diethylaminophenylcarbinol picrate, 0.0810 g, V 0.15 ml	4.00	0.755	1	—
	10.29	0.618	0.82	3.08
	10.58	0.545	0.72	3.03

*One milliliter of an acetone solution of diantipyrinyl-p-dimethylaminophenylcarbinol (c 10^{-3} M) was mixed with 9.00 ml of acetone and 0.10 ml of 0.1 N hydrochloric acid solution. After 2 days 0.75 ml aliquots of this solution were added to the series of buffer solutions.

and ferric hydroxides ceased to form. The drop method on filter paper employing potassium ferricyanide and potassium ferrocyanide was used to test for the complete precipitation of the iron ions. The precipitate was filtered; with vigorous stirring, the filtrate was again treated slowly with 20% NaOH solution until the red color of the solution disappeared. The obtained precipitate was filtered and dried at 80-85°. The crude carbinol was dissolved with heating in benzene and the hot solution was filtered. The filtrate was treated with 5% hydrochloric acid solution. The hydrochloric acid solution was separated from the benzene layer and neutralized with 20% NaOH solution. After neutralization of the hydrochloric acid, the NaOH solution was added slowly, in drops, until the color had disappeared completely. After recrystallization from a mixture of benzene and benzine the carbinol had m.p. 168-169°.

Found %: N 12.66, 12.70. $C_{33}H_{37}O_3N_5$. Calculated %: N 12.72.

To obtain the picrate of the dye we dissolved 0.55 g of the carbinol in 50 ml of 1% acetic acid solution and then added a solution of 0.25 g of picric acid in 25 ml of water. The obtained precipitate of the picrate was recrystallized from butyl alcohol.

Found %: N 14.72. M* 721, 726. $C_{33}H_{36}O_2N_5 \cdot C_6H_2O_7N_3$. Calculated %: N 14.70. M 763.

Diantipyrinyl-p-aminophenylcarbinol. A solution of 2.0 g of diantipyrinyl-p-aminophenylmethane dihydrochloride in 50 ml of 10% ferric chloride solution was heated for 5.5 hr on the boiling water bath. The free diantipyrinyl-p-aminophenylcarbinol was isolated from the solution in the same manner as the isolation of diantipyrinyl-p-diethylaminophenylcarbinol. After recrystallization from acetone, m.p. 190-191°.

Found %: N 14.29, 14.35. $C_{29}H_{29}O_3N_5$. Calculated %: N 14.13.

Picrate of the dye. A solution of 0.60 g of the carbinol in 20 ml of 5% acetic acid was mixed with a solution of 0.3 g of picric acid in 30 ml of water. The picrate was recrystallized from a mixture of alcohol and water (1 : 2).

Found %: N 16.12. M* 705, 715. $C_{29}H_{28}O_2N_5 \cdot C_6H_2O_7N_3$. Calculated %: N 15.86. M 707.

Determination of ionization constants. A weighed sample (a) of the carbinol or of the picrate of the dye was dissolved in 100 ml of acetone. The same amount (V) of this solution was then added to 25.0 ml aliquots of several buffer solutions, each having a different pH value. After equilibrium had been established, the optical density of the solution was measured using a Konig-Martens spectrophotometer at the wavelength corresponding to the maximum absorption. The layer thickness of all of the investigated solutions was 20 mm. The hydrolysis constants were calculated using the previously given equation [4].

SUMMARY

In the class of triarylmethane dyes a deepening of the color can be accompanied by an increase as well as a decrease in the stability of the dyes to hydrolysis.

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* Determined titanometrically.

AROMATIC FLUORO DERIVATIVES

IV. REPLACEMENT OF NITRO GROUP BY CHLORINE
IN NITROHALO DERIVATIVES OF BENZENE*

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F. F. Beilstein and A. A. Kurbatov [1] observed that the treatment of nitrobenzene with chlorine in the presence of antimony trichloride yields, in addition to chloronitro compounds, also a small amount of tetrachlorobenzene and hexachlorobenzene, i.e., the nitro group is replaced by the chlorine atom. Replacement of the nitro group by chlorine was also observed in the chlorination of other nitro compounds [2].

Replacement of nitro groups by chlorine may become the main process if the nitro compound is reacted with chlorine at a temperature of about 200° in the absence of nuclear-chlorination catalyst. Thus, the chlorination of the isomeric dinitrobenzenes at 200° gave the corresponding dichloro and chloronitro compounds [3]. The preparation of chloro- and dichlorophthalic anhydrides by the chlorination of the corresponding nitro compounds at 230-250° has been described [4]. This reaction can also have definite technical importance. L. S. Solodar and co-workers propose obtaining the chloro derivatives of benzoyl chloride by treating nitrotoluene with chlorine at 200-350° [5]. m-Dichlorobenzene has been obtained in industry by the chlorination of m-dinitrobenzene at 220° [6].

A number of other chloro derivatives of benzene, difficultly available by other procedures, can also be obtained in a similar manner [7].

Replacement of the nitro group by bromine [8] and by iodine [3] has also been described.

We studied the replacement of the nitro group by chlorine in various, chiefly fluorine-containing, nitrohalo compounds. The chlorination of fluoronitro compounds opens a new way of obtaining interesting but little studied, due to their difficult availability, fluorochloro and fluorochloronitro derivatives of benzene.

The treatment of 2,4-dinitrofluorobenzene with chlorine at 180-220° gave 2,4-dichlorofluorobenzene in up to 70% yield plus a mixture of fluorochloronitrobenzenes (15-30%).
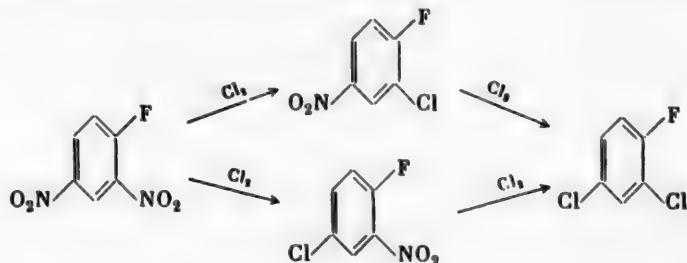
It is interesting to mention that the ratio of the isomeric 3-chloro-4-fluoro- and 2-fluoro-5-chloronitrobenzenes was 10 : 1, i.e., the nitro group ortho to the fluorine atom is cleaved more easily. In a similar manner, the chlorination of 2,4-dinitrochlorobenzene at 220-240° gave 61% of 1,2,4-trichlorobenzene and a mixture of the 3,4- and 2,5-dichloronitrobenzenes in a 7 : 3 ratio.

*For Communication III see Nauch. Doklady Vysshei Shkoly, Khim. Tekhnol. 1958, 346.

The reaction of chlorine with 2,4-dinitrobromobenzene (200-220°) gave only 1,2,4-trichlorobenzene, i.e., here both the nitro group and the bromine atom are replaced by chlorine. This result is not unexpected, since cases where the bromine is replaced by chlorine in the chlorination of organic bromine compounds are already known [9].

The chlorination of 4-fluoro-6-chloro-1,3-dinitrobenzene at 180-200° gave 2,4,5-trichlorofluorobenzene in 75% yield. This same compound is also obtained in 64% yield when 2,4-dichloro-5-fluoronitrobenzene (the nitration product of 2,4-dichlorofluorobenzene) is chlorinated [10]. From 4,6-difluoro-1,3-dinitrobenzene we obtained the previously unknown 4,6-dichloro-1,3-difluorobenzene in 77% yield.

Attempts to obtain 2,4,5-trifluorochlorobenzene by treating 2,4,5-trifluoronitrobenzene with chlorine proved unsuccessful. The reaction did not go in the interval 180-250°. At the same time, the chlorination of unsubstituted nitrobenzene (at 180-190°) readily gave chlorobenzene.

The reaction of replacing the nitro group by chlorine should be run in such manner that the chloro derivatives (boiling considerably below the starting products), in measure with their formation, are continuously distilled from the reaction mixture. The process stops when the reaction products accumulate in the reaction mass and starts anew after their removal by distillation. The chlorination of a mixture of equal amounts of 2,4-dinitrofluorobenzene and 2,4-dichlorofluorobenzene begins only after the main portion of the chloro derivative has been distilled off. An apparent explanation for this is that the reaction goes in the vapor phase.

Replacement of the nitro groups by chlorine atoms is most conveniently done in a heated fractionation column, where the chlorine is fed into the pot, while the nitro product is added from the top. In this way the process can be made continuous. If the reaction is run without the column, for example, in a Wurtz flask having the same volume as the still pot, then the rate of formation of the chloro derivatives proves to be 10 to 12 times slower. It should be mentioned that there is absolutely no tar formation during reaction.

This method is also convenient for obtaining a number of other chloro derivatives of benzene, for example, the m- and o-dichlorobenzenes.

The fact that the chlorination time is cut nearly in half when the reaction mass is irradiated with ultraviolet light makes it possible to assume that the reaction of replacing the nitro group by chlorine is a radical process.

EXPERIMENTAL

Chlorination of 2,4-dinitrofluorobenzene. a) The reaction was run in an apparatus consisting of a pear-shaped, three-necked, 100 ml flask, fitted with a sparger, descending to the bottom, for the admittance of monohydrate-dried chlorine, and a thermometer. The flask was connected to a column (length 35 cm, diameter 30 mm), filled with cut glass-tube pieces, which was electrically heated. Also, the column was fitted with a total reflux head. In the middle the column was fitted with an opening, through which by means of a dropping funnel the molten nitro compound was added continuously at a rate approximately equal to the rate at which the chlorination products distilled. The temperature in the flask was 220-230°, and 180-190° in the column; the rate of chlorine addition was 50-70 ml/min. The charge of nitro product in the flask was 100 g. Nitrogen oxides appear within several minutes after starting the passage of chlorine, and in another 15-20 min the reaction products begin to distill, after which the addition of the nitro compound is started. The process is run until all of the products have distilled from the flask. The chlorination of 600 g of 2,4-dinitrofluorobenzene was ended in 25-30 hr. The distilled products were decolorized by drawing air through them, and then they were distilled. We obtained 350-400 g (66-75%) of 2,4-dichlorofluorobenzene as a colorless liquid.

B.p. 169° (745 mm), f.p. −23°, $n^{20}D$ 1.5242, d^{20}_4 1.4092, MR_D 35.89; calc. 35.88. From the literature, b.p. 174° [11], 172°, f.p. −13° [12].

Founf %: F 11.2, 11.1; Cl 43.2. $C_6H_3FCl_2$. Calculated %: F 11.5; Cl 43.0.

The residue from the distillation of the 2,4-dichlorofluorobenzene was vacuum-distilled. We obtained 85-101 g (15-18%) of a mixture of 3-chloro-4-fluoro- and 2-fluoro-5-chloronitrobenzenes with b.p. 112-114° (25 mm). When this mixture was cooled to 0° we isolated 56-59 g of 3,4-chlorofluoronitrobenzene with m.p. 39°. After recrystallization from alcohol, m.p. 41.5. From the literature, m.p. 41° [13].

b) The apparatus for the chlorination consisted of two Wurtz flasks of the same volume, connected to each other by an adapter. All of the following experiments, except those discussed individually, were run in similar

equipment. Into the 100 ml reaction flask, fitted with a thermometer and a tube for admitting chlorine, both reaching to the bottom of the flask, we charged 50 g of 2,4-dinitrofluorobenzene. The reaction mass was heated by a spiral, wrapped around the flask, up to 190-210°, and then chlorine was bubbled into it (at a rate of 50-60 ml/min) until all of the reaction products had distilled (16-23 hr). The formation of nitrogen oxides was observed in approximately 30-50 min after the start of chlorine addition, and the product began to distill. We obtained 25-30 g (56-68%) of 2,4-dichlorofluorobenzene with b.p. 169-170° and 7-15 g (15-32%) of a mixture of isomeric chlorofluoronitrobenzenes with b.p. 110-111° (23 mm).

c) The reaction was run in a quartz Wurtz flask, irradiated with a PRK-4 ultraviolet lamp at a distance of 25 cm. The conditions were the same as in the preceding experiment. Here the formation of nitrogen oxides occurred within 1-3 min after the start of chlorine passage and the reaction product began to distill. The chlorination of 50 g of 2,4-dinitrofluorobenzene was ended in 9-11 hr. We obtained 56-60% of 2,4-dichlorofluorobenzene and 28-31% of mixed fluorochloronitrobenzenes.

Reaction of chlorine with a mixture of 2,4-dinitrofluorobenzene and 2,4-dichlorofluorobenzene. Chlorine was passed at a rate of 30-40 ml/min through a mixture of 6 g of 2,4-dinitrofluorobenzene and 6 g of 2,4-dichlorofluorobenzene at 190° for 5 hr. The reaction failed to go. Then the chlorine flow was discontinued and the 2,4-dichlorofluorobenzene was removed in portions of 0.6-0.8 g by distillation. After each distillation, chlorine was passed through the mixture for 1 hr. The reaction began only after the distillation of 4.4-4.6 g of 2,4-dichlorofluorobenzene.

Analysis of mixed fluorochloronitrobenzenes. Five grams of the mixed fluorochloronitrobenzenes was kept for a day at 0° and the deposited 3,4-chlorofluoronitrobenzene (3.15 g, m.p. 40°) was filtered. The filtrate (1.8 g) was heated under reflux for 12 hr with 15 ml of 5% NaOH solution. Then 10% HCl was added until the reaction was weakly acid to Congo and the mixture was steam-distilled. The distillate was extracted with ether. After evaporation of the ether we obtained 0.41 g of 4-chloro-2-nitrophenol with m.p. 85-86°. The residue from the steam distillation was extracted with ether to yield 1.31 g of 2-chloro-4-nitrophenol; m.p. 110° (from benzene). From the literature the melting points are respectively 86 and 111° [4].

Chlorination of 2,4-dinitrochlorobenzene. In the same manner as described above (Method b), 303.5 g of 2,4-dinitrochlorobenzene was chlorinated for 50 hr at 220-240° and a chlorine rate of 50-60 ml/min. We obtained 160-170 g (59-63%) of 1,2,4-trichlorobenzene with b.p. 134-136° (80 mm) and f.p. 16°, and 64-68 g (22-23.5%) of a mixture of 2,5- and 3,4-dichloronitrobenzenes with b.p. 128-132° (11 mm).

Analysis of mixed dichloronitrobenzenes. Into a 45 ml steel autoclave were charged 5 g of the mixed isomeric dichloronitrobenzenes and 32 ml of 8% NaOH solution, and the mixture was heated at 160-165° for 20 hr. The workup was the same as in the analysis of the mixed fluorochloronitrobenzenes. We obtained 1.2 g (27%) of 4-chloro-2-nitrophenol with m.p. 86° and 3.15 g (70%) of 2-chloro-4-nitrophenol with m.p. 109-110°.

Chlorination of 2,4-dinitrobromobenzene. Into the reaction flask of the chlorination apparatus was charged 60 g of 2,4-dinitrobromobenzene and then chlorine was passed in at 200° and a rate of 30-50 ml/min. An intense evolution of reddish-brown vapors began within 15-20 min, and within an hour the product began to distill, the distillation ending after 15-17 hr. We obtained 35-36 g (80-82%) of 1,2,4-trichlorobenzene with b.p. 111-113° (28 mm), 209° (747 mm), and f.p. 16°.

Preparation of 2,4,5-trichlorofluorobenzene. a) Chlorine was passed at a rate of 50-70 ml/min through a melt of 50 g of 4-fluoro-6-chloro-1,3-dinitrobenzene at 200-220° until the reaction products ceased to distill (10-12 hr). The nitrogen oxides appeared within 20-30 min after the start of chlorine passage, while the reaction product began to distill after another hour. We obtained 32-35 g (72-79%) of 2,4,5-trichlorofluorobenzene as long colorless needles with m.p. 64° (from petroleum ether) and b.p. 104-106° (35 mm), and 203-204° (750 mm). From the literature, m.p. 62° [15].

Found %: F 9.5, 10.3; Cl 53.3, 53.6. $C_6H_2FCl_3$. Calculated %: F 9.5; Cl 53.4.

b) When 15 g of 2,4-dichloro-5-fluoronitrobenzene was chlorinated at 200-220° for 12 hr and a chlorine rate of 40-50 ml/min we obtained 9-10 g (64-70%) of 2,4,5-trichlorofluorobenzene with m.p. 62° and b.p. 102-104° (32 mm).

Preparation of 4,6-dichloro-1,3-difluorobenzene. Chlorine was passed at a rate of 30-50 ml/min through a melt of 25 g of 4,6-difluoro-1,3-dinitrobenzene at 210-215° for 10-12 hr. We obtained 17-18 g (77-82%) of 4,6-dichloro-1,3-difluorobenzene as a colorless oil.

B.p. 167-168° (750 mm), f.p. 5°, $n^{20}D$ 1.5080, d^{20}_4 1.5088, MR_D 36.16; calc. 35.84.

Found %: F 20.6, 20.5. $C_6H_2F_2Cl_2$. Calculated %: F 20.8.

Chlorination of 2,4,5-trifluoronitrobenzene. In a 50 ml two-necked flask, fitted with a tube descending to the bottom for the admittance of chlorine and a fractionation column 25 cm long filled with glass packing, was placed 25 g of 2,4,5-trifluoronitrobenzene and then chlorine was bubbled in for 1½ hr. The temperature of the bath heating the flask was varied between 180 and 220°, while the temperature of the column was varied from 170-250°, and the chlorine rate was varied from 20 to 70 ml/min. 2,4,5-Trifluoronitrobenzene remains unchanged under these conditions.

2,4,5-Trifluoronitrobenzene also fails to react with chlorine at 180-210° even when the reaction mass is irradiated with ultraviolet light.

Chlorination of nitrobenzene. The reaction was run in the apparatus described in the preceding experiment (temperature in both flask and column, 190-200°) at a chlorine rate of 20-35 ml/min. From 30 g of nitrobenzene in 15 hr we obtained 13 g (48%) of chlorobenzene with b.p. 129° (741 mm), and $n^{16}D$ 1.5258.

Preparation of o-dichlorobenzene. The chlorination of 850 g of o-chloronitrobenzene was run in the same manner as that of 2,4-dinitrofluorobenzene (Method a). The reaction time was 32 hr. We obtained 672 g (85%) of o-dichlorobenzene with b.p. 180-185° (750 mm) and $n^{16.5}D$ 1.5539.

Preparation of m-dichlorobenzene. The chlorination of 150 g of m-dinitrobenzene by the above described procedure was ended in 5 hr. We obtained 102 g (73%) of m-dichlorobenzene with b.p. 172° and $n^{18}D$ 1.5460, and 12 g (9%) of m-chloronitrobenzene with b.p. 115-120° (50 mm), and m.p. 39-40°. After recrystallization from alcohol, m.p. 43°.

SUMMARY

1. A method was developed for obtaining fluorochlorobenzenes by the reaction of fluoronitro compounds with chlorine at 190-210°.

2. The reaction of replacing nitro groups by chlorine atoms takes place in the vapor phase and is probably a radical process.

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AROMATIC FLUORO DERIVATIVES

V. NITRATION OF FLUOROCHLOROBENZENES*

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It was shown by Ingold that in the nitration of fluoro-aromatic compounds a deactivation of the o-position due to the inductive effect of the fluorine atom plays a greater role than do steric factors [1]. This follows from an examination of the ratio of the isomers obtained in the nitration of fluoro- and chlorobenzenes and also of the o- and p-fluorochlorobenzenes [2-5]. There is no data in the literature on the mononitration of m-fluorochlorobenzene.
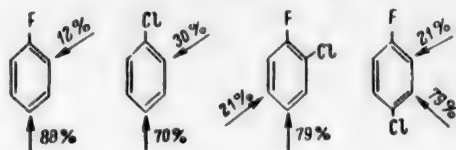
1,2,4-Trihalobenzenes normally nitrate in the 5-position, independent of the mutual distribution of the fluorine and chlorine atoms [6]. The nitration of 2,4-dichlorofluorobenzene gave us 2,4-dichloro-5-fluoronitrobenzene and 2,4-dichloro-5-fluoro-1,3-dinitrobenzene [7]. 1,2,4,5-Tetrachlorobenzene forms the mononitro derivative with ease and the dinitro compound with considerably more difficulty [8]. 1,2,4,5-Tetrafluorobenzene is oxidized when treated with mixed acid with the formation of 2,5-difluoroquinone [9].

We established that the mononitro derivatives are obtained smoothly when 2,4,5-trichlorofluorobenzene and 4,6-dichloro-1,3-difluorobenzene are nitrated under the conditions used to nitrate 1,2,4,5-tetrachlorobenzene. In this connection the difluorodichlorobenzene is nitrated with somewhat greater difficulty than the fluorotrichlorobenzene and tetrachlorobenzene. Attempts to obtain the dinitro compounds proved unsuccessful.

The structure of the nitration product (I) of 2,4,5-trichlorofluorobenzene was shown in the following manner. When treated with chlorine at 200-220° it was converted in 92% yield to tetrachlorofluorobenzene (II), identical with the chlorination product of the known 2,4-dichloro-5-fluoro-1,3-dinitrobenzene (III).

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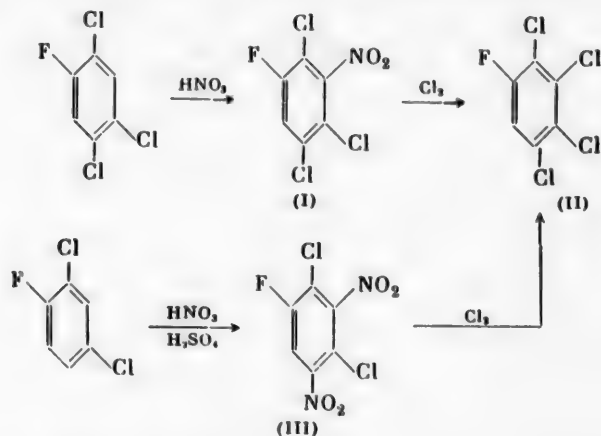
* For Communication IV see Zhur. Obshch. Khim. 31, 1222 (1961).

The identity of the tetrachlorofluorobenzenes (II), obtained by the chlorination of compounds (I) and (III), was shown by the exact identity of their infrared spectra.[*]

The position of the nitro group in the dichlorodifluoronitrobenzene can be determined with a certain degree of probability by comparing the ultraviolet spectra of the tetrahalonitrobenzenes (figure). As is known [10], in 2,6-dichloronitrobenzene the nitro group is drawn out of the plane of the benzene ring, as a result of which a peak in the vicinity of 250 mμ, characteristic for coplanar nitro compounds, is missing for this compound.

As can be seen (figure), the spectra of all three tetrahalonitrobenzenes have the same character. In the case of the tetrachloro- and trichlorofluoronitrobenzenes it is known that the nitro group is found between two chlorine atoms. Starting with this, there is sufficient reason to assume that in the dichlorodifluoronitrobenzene the nitro group is also found between two chlorine atoms. As a result, both in the nitration of 2,4,5-trichlorofluorobenzene and 4,6-dichloro-1,3-difluorobenzene the nitro group enters the free position between the chlorine atoms, i.e., the polar effect of fluorine atoms proves to be stronger than steric hindrance.
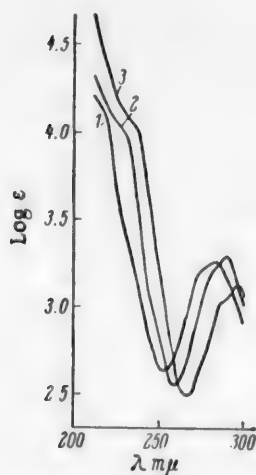
EXPERIMENTAL

Ultraviolet spectra of solutions (c 10^{-3} M) of tetrahalonitrobenzenes in heptane. (SF-4 spectrophotometer). 1) 2,6-Dichloro-3,5-difluoronitrobenzene; 2) 2,3,6-trichloro-5-fluoronitrobenzene; 3) 2,3,5,6-tetrachloronitrobenzene.

2,4-Dichloro-5-fluoronitrobenzene. Into a four-necked flask, fitted with a stirrer, reflux condenser, dropping funnel and thermometer, was charged 26 g of 2,4-dichlorofluorobenzene. Then the product was cooled to 5° and mixed acid (14 ml of 95% HNO_3 and 8 ml of 95% H_2SO_4) was added at such a rate that the temperature did not rise above 25°. After this 30 g of 15% oleum was added, and the mixture was heated for 3 hr at 50-60°, poured over ice, and extracted with benzene. By distillation we isolated 29-31 g (88-94%) of 2,4-dichloro-5-fluoronitrobenzene as a pale yellow oil.

B.p. 127° (17 mm), f.p. 5.5°, $d^{16.5}_4$ 1.6028, $n^{18.5}$D 1.5674.

Found %: N 6.55, 6.42. F 8.6, 8.4. $C_6H_2O_2NFCl_2$. Calculated %: N 6.68; F 9.1.

The still residue was recrystallized from alcohol to give 2-2.7 g (5-7%) of 2,4-dichloro-5-fluoro-1,3-dinitrobenzene (III) as pale yellow needles with m.p. 73-74°.

Found %: N 11.23, 11.14. $C_6HO_4N_2FCl_2$. Calculated %: N 11.00.

2,4-Dichloro-5-fluoro-1,3-dinitrobenzene (III). Twenty grams of 2,4-dichlorofluorobenzene was added in drops to mixed acid (67 ml of 99% HNO_3 and 55 ml of the monohydrate), after which the mixture was heated on the boiling water bath for 4 hr. After cooling, the reaction mass was poured over ice and then filtered. We obtained 28-30 g (87-93%) of 2,4-dichloro-5-fluoro-1,3-dinitrobenzene as pale yellow needles (from alcohol). M.p. 74-74.5°.

2,3,6-Trichloro-5-fluoronitrobenzene (I). To 112 ml of 99% HNO_3 was gradually added 12 g of 2,4,5-trichlorofluorobenzene, after which the mixture was heated for 6 hr at 60-70°, then poured over ice, and filtered. We obtained 12-12.2 g (81-83%) of the trichlorofluoronitrobenzene as colorless needles with m.p. 64-64.5° (from petroleum ether).

Found %: N 5.92, 5.73; F 7.7, 8.0. $C_6HO_2NFCl_3$. Calculated %: N 5.73; F 7.8.

2,6-Dichloro-3,5-difluoronitrobenzene. Using the above described procedure, 5 g of 4,6-dichloro-1,3-difluorobenzene was nitrated with 50 ml of 99% HNO_3. We obtained 3.3-3.4 g (52-53%) of the dichlorofluoronitrobenzene as long colorless needles (from petroleum ether). M.p. 42°.

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[*] The spectra of 3% solutions in CCl_4 were taken using an IKS-14 spectrophotometer with NaCl prism, in the range 800-1600 cm^{-1}. The layer thickness was 0.01 mm. Absorption bands were found at 841, 851, 971, 1114, 1142, 1362, 1419, 1555 and 1573 cm^{-1}. The spectra were taken by V. A. Plakhov.

Found %: N 6.16, 6.30; F 17.3, 17.9. $C_6HO_2NF_2Cl_2$. Calculated %: N 6.14; F 16.8.

2,3,4,5-Tetrachlorofluorobenzene (II). a) Using the earlier described procedure [11], 20 g of 2,4-dichloro-5-fluoro-1,3-dinitrobenzene (III) was chlorinated for 13 hr at 200-220°. The product that distilled during chlorination was dissolved in ether, washed with water until neutral to litmus, and then dried over sodium sulfate. By distillation we obtained 16.8 g (92%) of 2,3,4,5-tetrachlorofluorobenzene (II) as a colorless waxy substance with b.p. 140-143° (46 mm), and m.p. 63-64°. Fine colorless needles with m.p. 66° (from alcohol).

Found %: F 7.9, 8.2; Cl 60.1, 59.9. C_6HFCl_4. Calculated %: F 8.1; Cl 60.7.

b) The treatment of 10.6 g of 2,3,6-trichloro-5-fluoronitrobenzene (I) with chlorine for 14 hr at 200-220° gave 9.3 g (92%) of 2,3,4,5-tetrachlorofluorobenzene (II) with m.p. 66.5° (from alcohol). The mixed melting point with the product obtained in the preceding experiment was not depressed.

SUMMARY

The nitration of fluorochlorobenzenes gave 2,4-dichloro-5-fluoronitrobenzene, 2,4-dichloro-5-fluoro-1,3-dinitrobenzene, 2,6-dichloro-3,5-difluoronitrobenzene, and 2,3,6-trichloro-5-fluoronitrobenzene.

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AROMATIC FLUORO DERIVATIVES

VI. CATALYTIC REDUCTION OF AROMATIC FLUORONITRO COMPOUNDS*

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Fluorine-containing aromatic amines can prove to be interesting starting materials for the synthesis of a number of medicinals, pesticides and dyes. Usually the fluoroanilines are obtained by the reduction of the corresponding nitro compounds. The reduction of fluoronitro compounds using iron [1, 2], zinc [3], tin [4], stannous chloride [5] and some other reducing agents has been described. Examples are also known of the catalytic reduction of fluorine-containing nitro compounds. The reduction of fluoronitro compounds with hydrogen has been done over platinum [6], palladium [4, 7] and skeletal nickel [8]. The reactions were run under a slight pressure (2-3 atm) at 20-80°.

It was shown by us that the hydrogenation of aromatic fluorine- and chlorine-containing nitro compounds over palladium black or skeletal nickel at room temperature (16-20°) and atmospheric pressure gives the corresponding amines in high yield. In this connection the palladium black may be used 4-5 times for hydrogenation before regenerating the catalyst. The halogen atoms are not cleaved under these conditions.

In this manner we were able to obtain o-, m- and p-fluoroanilines, 3-chloro-4-fluoroaniline, 2,4,5-trifluoroaniline, 2,4-difluoro-5-chloroaniline, 2,4-dichloro-5-fluoroaniline, 2,3,5,6-tetrachloroaniline, 2,3,6-trichloro-5-fluoroaniline, and 2,6-dichloro-3,5-difluoroaniline.

It is interesting to mention that the pure fluoroanilines are quite stable and do change when stored for a long time. At the same time the products isolated directly from the reaction mass, on standing in the air for several days, are converted to a dark tarry mass.

Fluorine-containing phenylenediamines can also be obtained by hydrogenation in the presence of palladium black or skeletal nickel. Using this procedure, we obtained the previously unknown 4-fluoro-1,3-phenylenediamine, 4,6-difluoro-1,3-phenylenediamine and 4-fluoro-6-chloro-1,3-phenylenediamine. The first two bases are so unstable that we were unable to obtain them in the free state.

EXPERIMENTAL

Preparation of skeletal nickel paste. The catalyst paste was washed with distilled water until neutral to litmus, and then 4-5 times with alcohol. The catalyst was stored under a layer of alcohol.

Hydrogenation of mononitrohalo derivatives. A solution of 0.5-2 g of the mononitro compound in 20-50 ml of alcohol was hydrogenated with vigorous shaking at 16-20° and atmospheric pressure over either palladium black (5% on weight of nitro compound) or skeletal nickel paste (50% on weight of nitro compound). The hydrogenation was run until the absorption of hydrogen ceased (2-6 hr). The solution was decanted from the catalyst and the latter was rinsed twice with 10 ml portions of alcohol. The rinse alcohol was combined with the main solution and the alcohol was distilled in vacuo at 20-25 mm. The thus obtained amine was either distilled or recrystallized from aqueous alcohol. The results of the experiments are summarized in the table.

The acetyl derivatives of fluoroanilines (I-VII) were obtained by refluxing the amine (0.2-0.4 g) with acetic anhydride (1-2 ml) for 1 hr. The solution was then poured into water and the obtained precipitate was recrystallized from aqueous alcohol.

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* For Communication V see Zhur. Obshch. Khim. 31, 1227 (1961).

Haloanilines, Obtained by the Hydrogenation of Mononitro Compounds

No.	Compound	Empirical formula	Yield (in %)	Melting point	% N found	% N calc.	Aceyl derivatives melting point	Aceyl derivatives empirical formula	% N found	% N calc.
I	2-Fluoroaniline	C_6H_6NF	92—95	B. P. 174—175°(750) (175—176 [5])*	—	—	79° (80) [9]	C_8H_8ONF	—	—
II	3-Fluoroaniline	C_6H_6NF	92—94	B. P. 186—188 (755) (186 [10])*		—	84 (85) [10]	C_8H_8ONF	—	—
III	4-Fluoroaniline	C_6H_6NF	95—96	B. P. 186—187 (760) [185—187 (763) [5]]*	—	—	150 (150) [5]	C_8H_8ONF	—	—
IV	3-Chloro-4-fluoro-aniline	C_6H_5NFCl	95—97	46 (44) [1]	9.73, 9.81	9.62	115	C_8H_7ONFCl	7.57, 7.44	7.46
V	2,4,5-Trifluoroaniline	$C_6H_4NF_3$	90—92	60 (60) [11]	—	—	130 (130) [11]	$C_8H_6ONF_3$	—	—
VI	2,4-Difluoro-5-chloro-aniline	$C_6H_4NF_2Cl$	91—95	50 (51) [1]	8.73, 8.80	8.56	141 (142) [1]	$C_8H_6ONF_2Cl$	6.73, 6.52	6.81
VII	2,4-Dichloro-5-fluoro-aniline	$C_6H_4NFCl_2$	92—96	70 (67) [12]	8.04, 7.89	7.78	127 (126) [12]	$C_8H_6ONFCl_2$	8.46, 6.32	6.30
							Diacetyl derivatives			
VIII	2,3,5,6-Tetrachloro-aniline	$C_6H_3NCl_4$	98—99	108 (108) [13]	— —	—	176 (175) [13]	$C_{10}H_7O_2NCl_4$	4.62, 4.52	4.45
IX	2,3,6-Trichloro-5-fluoroaniline	$C_6H_3NFCl_3$	96—99	64	6.76, 6.83	6.52	104	$C_{10}H_7O_2NFCl_3$	4.82, 4.75	4.69
X	2,6-Dichloro-3,5-di-fluoroaniline	$C_6H_3NF_2Cl_2$	90—93	73	7.14, 7.18	7.10	118	$C_{10}H_7O_2NF_2Cl_2$	5.08, 4.89	4.97

* Boiling point given in the literature.

The diacetyl derivatives of amines (VIII-X) were obtained by refluxing 0.2-0.3 g of the product with 1-1.5 ml of acetic anhydride for 1-2 min in the presence of several drops of conc. sulfuric acid. Further treatment was the same as described above.

Preparation of halo derivatives of m-phenylenediamine. 4-Fluoro-1,3-phenylenediamine. A solution of 1 g of 2,4-dinitrofluorobenzene in 30 ml of alcohol was hydrogenated with vigorous shaking at 16-18° and atmospheric pressure over either 0.1 g of palladium black or 0.8 g of skeletal nickel paste for 4-6 hr. On conclusion of hydrogen absorption the alcohol solution was decanted from the catalyst and hydrogen chloride was passed through it for 10-15 min. We isolated 0.92-1.0 g (86-93%) of 4-fluoro-1,3-phenylenediamine dihydrochloride as either a colorless or grayish powder.

Found %: F 10.4, 9.9. $C_6H_7N_2F \cdot 2HCl$. Calculated %: F 9.6.

To 0.5 g of 4-fluoro-1,3-phenylenediamine dihydrochloride in 3 ml of pyridine was added 2 ml of benzoyl chloride and the mixture was heated at 50-60° for 1 hr. After cooling, the solution was poured into 100 ml of water. We obtained 0.45-0.49 g of the dibenzoyl derivative. After recrystallization from aqueous alcohol the compound was obtained as colorless plates with m.p. 204-204.5°.

Found %: N 7.98, 8.11; F 6.0, 5.9. $C_{20}H_{15}O_2N_2F$. Calculated %: N 8.14; F 5.7.

4,6-Difluoro-1,3-phenylenediamine. Using the above described procedure, the hydrogenation of 2 g of 4,6-difluoro-1,3-dinitrobenzene in 50 ml of alcohol over either 0.2 g of palladium black or 1.5 g of skeletal nickel paste gave 1.7-1.8 g (79-84%) of 4,6-difluoro-1,3-phenylenediamine dihydrochloride as a grayish powder.

The dibenzoyl derivative was obtained as colorless plates with m.p. 205° (from alcohol).

Found %: N 7.71, 7.66; F 10.1, 10.4. $C_{20}H_{14}O_2N_2F_2$. Calculated %: N 7.95; F 10.8.

4-Fluoro-6-chloro-1,3-phenylenediamine. A solution of 2 g of 4-fluoro-6-chloro-1,3-dinitrobenzene in 50 ml of alcohol was hydrogenated over either 0.2 g of palladium black or 1.6 g of skeletal nickel paste until the absorption of hydrogen ceased (5-7 hr). The solution of the amine was decanted from the catalyst and the alcohol was distilled in vacuo. We obtained 1.35-1.4 g (91-95%) of 4-fluoro-6-chloro-1,3-phenylenediamine as slightly pink plates with m.p. 124-125° (from a mixture of equal volumes of benzene and petroleum ether).

Found %: N 17.45, 17.54; F 10.9. $C_6H_6N_2FCl$. Calculated %: N 17.44; F 11.8.

The diacetyl derivative was obtained by refluxing the amine with acetic anhydride for 1 hr. M.p. 254-255° (from alcohol).

Found %: N 11.28, 11.17. $C_{10}H_{10}O_2N_2FCl$. Calculated %: N 11.46.

SUMMARY

It was shown that the fluoro and chloro derivatives of nitro- and m-dinitrobenzene are smoothly reduced by hydrogen over either palladium black or skeletal nickel at room temperature and atmospheric pressure.

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INVESTIGATIONS IN THE FIELD OF SYNTHETIC DYES

XVIII. SYNTHESIS OF ISOMERIC QUATERNARY SALTS OF N-ARYL QUINALDINIUM AND THEIR CONVERSIONS

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As a result of ortho-cyclicization of unsymmetrical aromatic amines with paraldehyde, acetaldehyde or vinyl ethers to N-aryl quinoline derivatives, the isomeric compounds (I) and (II) may be formed.

When we condensed p-methoxydiphenylamine with vinylbutyl ether or paraldehyde, isomers were formed.
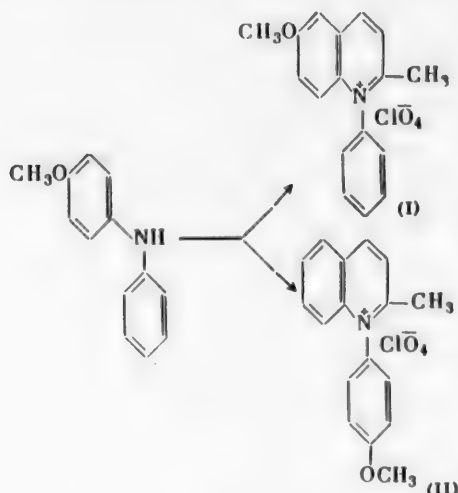
We isolated these two isomeric quaternary salts in the form of the perchlorates, investigated their principal properties and used them as the basis for obtaining some very simple cyanine dyes. The isomeric compounds were separated by fractional crystallization or fractional precipitation with sodium perchlorate. The structure of the salts was confirmed by the fact that the light absorption maxima of the cyanine dyes obtained from them agree completely with the absorption maxima of similar isomeric dyes. It should be mentioned that in the case of condensation with vinylbutyl ether, a higher yield of one of the isomers is obtained than with paraldehyde. In the case of the synthesis of small amounts of the salts the first isomer can only be detected qualitatively by a reaction with orthoformic ester with a cyanine dye, but it cannot be isolated quantitatively without using chromatography. The investigation of condensation with vinylbutyl ether was carried out under different temperature conditions and it was noted that heating the reaction mixture at 100° gave a 37% yield of the salts, while if the reaction mass was boiled (104-106°) the yield was increased to 85%. The yield of 1-p-methoxyphenyl-quinaldinium perchlorate (II) was approximately 10-fold more than the yield of the other isomer.

By condensation of the isomeric salts with orthoformic ester, methyl mercaptobenzthiazole ethiodide, quinoline methiodide, methyl benzthiazole ethiodide, trimethyl indolenine methiodide and p-dimethyl aminobenzaldehyde we obtained cyanine dyes of different structure. A methoxy group in the 6 position of the quinoline ring has a considerable bathochromic effect (Table 1), displacing the absorption maximum into the longwave part of the spectrum

TABLE 1

R	R'	z	n	Absorption maximum, $m\mu$ *	Displacement of the absorption maximum with respect to unsubstituted compounds [1-5]
H	C_6H_5	a	3	614	—
H	p-$CH_3OC_6H_4$	b	3	617	3
CH_3O	C_6H_5	c	3	635	21
H	C_6H_5	d	1	560	—
H	p-$CH_3OC_6H_4$	d	1	562	2
CH_3O	C_6H_5	d	1	572	12
H	C_6H_5	e	1	495	—
H	p-$CH_3OC_6H_4$	e	1	495	—
CH_3O	C_6H_5	e	1	505	10
H	C_6H_5	e	3	586	—
H	p-$CH_3OC_6H_4$	e	3	590	4
CH_3O	C_6H_5	e	3	596	10

* The spectra of the alcoholic solutions were determined with an SF-2M spectrophotometer.

by 21 $m\mu$, 10 $m\mu$ and 10 $m\mu$ as compared with unsubstituted carbocyanine, isocyanine and pseudoquinothiacyanine respectively. A methoxy group in a different position of quinoline, i.e., with a phenyl radical at the nitrogen (II), gives an insignificant bathochromic displacement as compared with unsubstituted compounds. This indicates that in the first case the substituents, present in the main ring of the perichrome, play a much greater part in the electronic reaction mechanism of the main chromophore than when these substituents are present in a radical attached to the heteroatom of nitrogen [1-5].
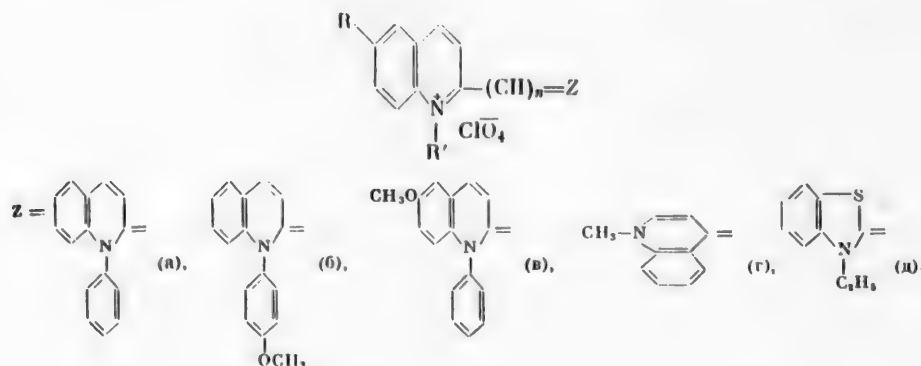
EXPERIMENTAL

The synthesis of isomeric quaternary salts (I) and (II). We placed 4 g of p-methoxydiphenylamine, 30 ml of water and 1.8 ml of hydrochloric acid (d 1.19) in a round-bottomed flask, equipped with a mechanical stirrer, condenser and dropping funnel. A volume of 11 ml of vinylbutyl ether was added dropwise in 1 hour at 90° with vigorous stirring, after which the contents were heated at 90-95° for 3 hours. To extract the quaternary salts, 40 ml of hot water was added to the flask containing the reaction mixture. After they had been boiled and stirred for 15 minutes, the contents of the flask were transferred to a beaker. After 5-10 minutes the homogeneous reaction mixture seperated into layers. The upper aqueous layer was decanted and both isomeric salts were isolated from it.

Precipitation of 1-phenyl-6-methoxyquinaldinium perchlorate (I). A volume of 15 ml of a 5% sodium perchlorate solution was added to a hot aqueous solution. The tar formed during this process was removed. After the filtrate had been left to stand overnight, crystals of the less soluble isomeric salt were precipitated; these were a

TABLE 2

Substance No.	Formulae of the dyes	Yield (%)	Melting point	Absorption maximum (in mμ)	Empirical formula	Found (%)		Calculated (%)	
						Cl	N	Cl	N
III	(structure)	50	248—250° (Decomp.)	635	$C_{35}H_{29}O_6N_2Cl$	5.81	4.69	5.83	4.59
IV	(structure)	62	282 (Decomp.)	617	$C_{35}H_{29}O_6N_2Cl$	5.79	4.89	5.83	4.59
V	(structure)	40	168—170 (Decomp.)	572	$C_{27}H_{23}O_3N_2Cl$	7.10	5.64	7.22	5.70
VI	(structure)	54	245—247	562	$C_{27}H_{23}O_3N_2Cl$	7.35	5.98	7.22	5.70

Table 2 (continued)
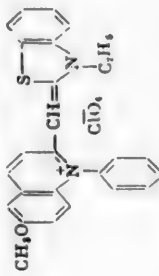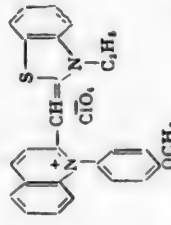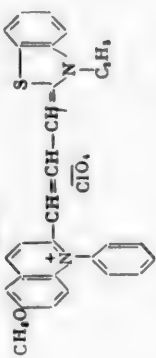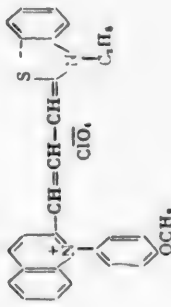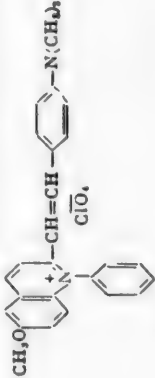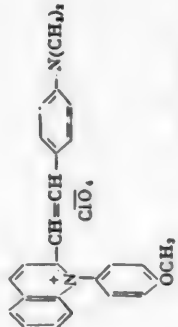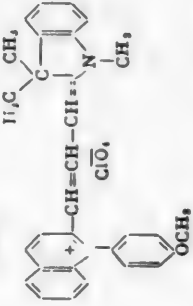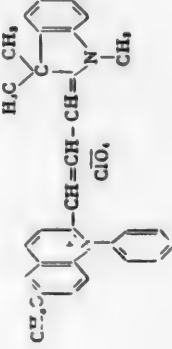
Substance No.	Formulae of the dyes	Yield (%)	Melting point	Absorption maximum (in mμ)	Empirical formula	Found (%)		Calculated (%)	
						Cl	N	Cl	N
VII		30	244—245 (Decomp.)	485, 504	$C_{26}H_{23}O_5N_2SCl$	6.86	5.42	6.93	5.48
VIII		40	255—258	466, 495	$C_{26}H_{23}O_5N_2SCl$	7.11	5.52	6.93	5.48
IX		66	163 (Decomp.)	596	$C_{28}H_{25}O_5N_2SCl$	6.54	5.30	6.60	5.21
X		50	227—230 (Decomp.)	590	$C_{28}H_{25}O_5NCl$	6.50	5.24	6.60	5.21

Table 2 (continued)

Substance No.	Formulae of the dyes	Yield (%)	Melting point	Absorption maximum (in $m\mu$)	Empirical formula	Found (%)		Calculated (%)	
						Cl	N	Cl	N
XI	(structure)	35	229—230	544	$C_{26}H_{25}O_3N_2Cl$	6.95	5.73	7.37	5.82
XII	(structure)	75	218—220	550	$C_{26}H_{25}O_3N_2Cl$	7.23	6.10	7.37	5.82
XIII	(structure)	85	223—225	574	$C_{30}H_{29}O_3N_2Cl$	6.39	—	6.65	—
XIV	(structure)	36	207	576	$C_{30}H_{29}O_3N_2Cl$	7.01	—	6.65	—

light-cream color on the bottom of the beaker, but whiter or colorless on the walls of the latter. The solution (filtrate I) was carefully decanted, and the crystals were treated in the beaker with 15 ml of boiling water. A light-pink molten mass of the quaternary salt collected on the bottom of the beaker; the aqueous layer (filtrate II) was decanted and the salt which hardened on cooling was ground to a light-cream powder, which melted at 203-205° when dried. After recrystallization from a large amount of water, the salt melted at 205°; the yield was 0.2 g (3.1%).

Found %: Cl 10.09, 10.27. $C_{17}H_{16}O_5NCl$. Calculated %: Cl 10.13.

Precipitation of 1-p-methoxyphenyl-quinaldinium perchlorate (II). The above-obtained filtrates (I) and (II) were evaporated to half the volume, and 10 ml of a 5% sodium perchlorate solution was added to the hot solution. When the perchlorate was added, a colorless crystalline precipitate of the quaternary salt was formed immediately; this was allowed to stand and was then filtered. After recrystallization from water, salt (II) melted at 154-156°; the yield was 2.2 g (34.3%).

Found %: N 4.49, 4.32; Cl 10.37, 20.33; OCH$_3$ (by the Zeisel test) 8.43. $C_{17}H_{16}O_5NCl$. Calculated %: N 4.00; Cl 10.13; OCH$_3$ 8.87.

Synthesis of Dyes (Table 2)

Bis(1-phenyl-6-methoxyquinolyl-2)-trimethine cyanine perchlorate (III). A quantity of 0.3 g of 1-phenyl-6-methoxyquinaldinium perchlorate, 0.18 g of orthoformic ester and 4 ml of pyridine were heated to boiling for 3 hours. To precipitate the dye, the reaction mixture was treated with hot water and the precipitate was recrystallized from alcohol.

Bis(1-p-methoxyphenyl quinolyl-2)-trimethine cyanine perchlorate (IV). A quantity of 1 g of 1-p-methoxyphenyl-quinaldinium perchlorate and 0.5 g of orthoformic ester were heated with boiling in 5 ml of pyridine for 3 hours; 10 ml of boiling water was then added to the hot reaction mass. The precipitated crystals were filtered and crystallized from ethanol in the form of lustrous green crystals.

(1-Phenyl-6-methoxyquinolyl-2)-(1'-methyl quinolyl-4) monomethine cyanine perchlorate (V). A quantity of 0.3 g of 1-phenyl-6-methoxy-quinaldinium perchlorate and 0.36 g of quinoline methiodide were heated with boiling in 15 ml of anhydrous alcohol, and 2 ml of 5% alcoholic caustic potash was added; the reaction mixture was then heated on a boiling water bath for 1 hour. The dye was precipitated with water and recrystallized from alcohol.

(1-p-Methoxyphenyl quinolyl-2)-(1'-methyl quinolyl-4')-monomethine cyanine perchlorate (VI). A quantity of 1.04 g of 1-p-methoxyphenylquinaldinium perchlorate and 1.04 g of quinoline methiodide were dissolved in 10 ml of anhydrous alcohol with heating. A quantity of 0.22 g of caustic potash, dissolved in 2 ml of alcohol, was added to the hot solution. After 20 minutes boiling, the dye was precipitated with water and was crystallized from aqueous alcohol.

(1-Phenyl-6-methoxy quinolyl-2)-(3'-ethyl benzthiazolyl-2')-monomethine cyanine perchlorate (VII). Equimolecular amounts of 1-phenyl-6-methoxyquinaldinium perchlorate and 2-methyl mercaptobenzthiazole were triturated with anhydrous sodium acetate and were heated to boiling in 3 ml of anhydrous alcohol for 30 minutes. The dye was precipitated as a light-brown powder.

(1-p-Methoxyphenyl quinolyl-2)-(3'-ethyl benzthiazolyl-2')-monomethine cyanine perchlorate (VIII). A quantity of 0.68 g of 1-p-methoxyphenyl quinaldinium perchlorate, 0.66 g of 2-methyl mercaptobenzthiazole ethiodide and 0.25 g of anhydrous sodium acetate were dissolved in 10 ml of alcohol and boiled for 20 minutes. The recrystallized dye (from alcohol) was bright-orange.

(1-Phenyl-6-methoxy quinolyl-2)-(3'-ethyl benzthiazolyl-2')-trimethine cyanine perchlorate (IX). A quantity of 0.75 g of 1-phenyl-6-methoxyquinaldinium perchlorate, 0.075 g of 2-β-acetanilidovinyl benzthiazole and 2 ml of pyridine were heated to boiling for 1.5 hours. To precipitate the dye, the reaction mixture was poured into 100 ml of hot water. The next day the lustrous green crystals of the dye were filtered, and recrystallized from alcohol.

(1-p-Methoxyphenyl quinolyl-2)-(3'-ethyl benzthiazolyl-2')-trimethine cyanine perchlorate (X). A quantity of 0.78 g of 1-p-methoxyphenyl quinaldinium perchlorate, 0.65 g of 2-β-acetanilidovinyl benzthiazole ethiodide and 5 ml of pyridine were heated to boiling for 1 hour. The dye was crystallized from ethyl and then from methyl alcohol.

(1-Phenyl-6-methoxy quinolyl-2)-p-dimethylaminostyril perchlorate (XI). We heated 0.1 g of 1-phenyl-6-methoxyquinaldinium perchlorate, 0.06 g of p-dimethyl aminobenzaldehyde and 2 ml of pyridine for 2 hours (to boiling); the dye was then precipitated with hot water and recrystallized from aqueous alcohol.

(1-p-Methoxyphenyl quinolyl-2)-p-dimethyl aminostyril perchlorate (XII). A quantity of 1.5 g of 1-p-methoxyphenyl quinaldinium perchlorate, 0.9 g of p-dimethyl aminobenzaldehyde and 2 ml of pyridine were heated for 1 hour. The styril was precipitated in the form of dark crystals.

(1-p-Methoxyphenyl quinolyl-2)-(1',3',3'-trimethyl indolenine-2')-trimethine cyanine iodide (XIII). A mixture of 0.3 g of 1-p-methoxyphenylquinaldinium perchlorate, 0.3 g of 2-β-acetanilidovinyldimethyl indolenine and 1.5 ml of pyridine were heated for 2 hours. The dye crystallized from aqueous alcohol as dark-green crystals.

(1-Phenyl-6-methoxy quinolyl-2)-(1',3',3'-trimethyl indolenine-2')-trimethine cyanine perchlorate (XIV). We heated 0.3 g of 1-phenyl-6-methoxyquinaldinium perchlorate, 0.25 g of 2-β-acetanilidovinyldimethyl indolenins methiodide, 0.5 ml of acetic anhydride and 2 ml of pyridine to boiling for 1 hour. The dye was precipitated with water and was crystallized from aqueous alcohol.

SUMMARY

1. 1-p-Methoxyphenyl quinaldinium and 1-phenyl-6-methoxy quinaldinium perchlorates were obtained by condensing p-methoxy diphenylamine with paraldehyde or vinylbutyl ether.

2. Symmetrical and unsymmetrical isomeric carbocyanines, isocyanines, pseudoquinothiacyanines and styrils were synthesized from these salts. Except for the styrils, all the dyes containing a methoxy group in the 6 position of the quinoline ring have a deeper color than the isomeric dyes.

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INVESTIGATIONS IN THE FIELD OF SYNTHETIC DYES

XXI. STYRILS OF DERIVATIVES OF N-ARYL QUINALDINIUM QUATERNARY SALTS

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We have shown that onium compounds of quinoline with aromatic radicals at the cyclic nitrogen condense at the active α- or γ-methyl group with o-ethers, carbonyl-containing organic compounds, nitroso compounds, diazonium salts, etc. with the formation of various types of dyes [1-6].

Continuing our investigations, we condensed p-acetylaminobenzaldehyde with some derivatives of N-aryl quinaldine quaternary salts; during this work we obtained dyes of the styril type. Styril derivatives with alkyl radicals attached to the heteroatom of nitrogen are described in the literature, some of these having a marked biologic effect [7-9].

It was of interest to investigate acyl amino-substituted styrils, containing aromatic radicals attached to the nitrogen of the heterocyclic group. Our experiments on the synthesis of styrils were carried out according to the system:
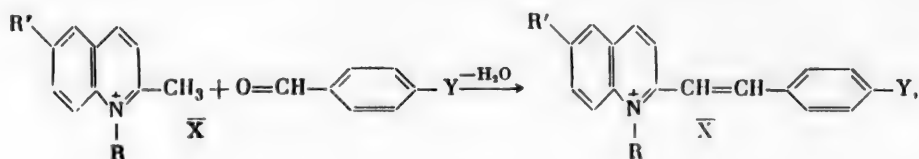
We investigated the principal properties of the synthesized styrils and obtained curves of the absorption in the visible part of the spectrum (see table). For comparison, this table also gives the absorption maxima of amino-substituted styrils ($Y = NH_2$) given in the literature.
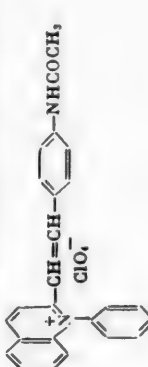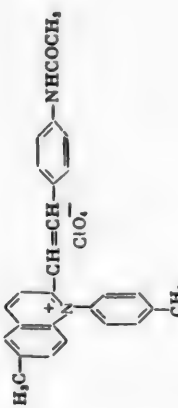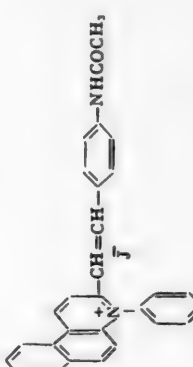
From the data of the table it is evident that the absorption maxima of the dyes of a number of p-acetyl aminostyrils are displaced hypsochromically by approximately 90-100 mμ in comparison with the corresponding dyes of a number of p-aminostyrils. This relatively large displacement of the absorption maximum indicates different energy levels of the molecules of the dyes in their basic state. This is explained by the fact that acylation of the amino group reduces markedly the mobility of the undivided electron pair of the nitrogen atoms of the amino group, reducing its participation in the reaction with the π-electrons of the cloud.
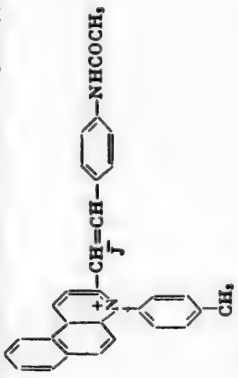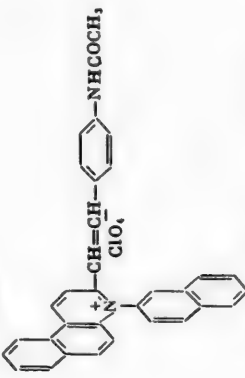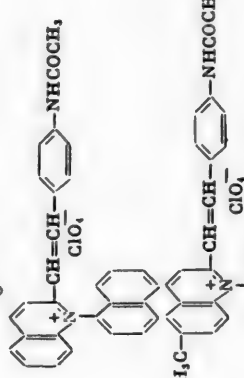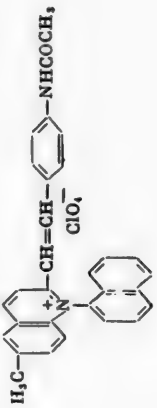
The properties of dyes synthesized by condensation of p-acetyl aminobenzaldehyde with quaternary salts are completely identical to those of the styrils which we obtained by condensing quaternary salts with p-aminobenzaldehyde and subsequent acetylation of the amino group of the dyes by acetic anhydride: the absorption spectra were the same for the dyes; mixed melts showed no depression of the melting point.

Acetyl-substituted styrils are more soluble in alcohol and in water than the corresponding amino-substituted styrils.

EXPERIMENTAL

(1-Phenyl quinolyl-2)-p-acetyl aminostyril perchlorate (I). A quantity of 0.4 g of 1-phenyl quinaldinium perchlorate, 0.20 g of p-acetyl aminobenzaldehyde and 2 ml of pyridine were heated in a flask with a reflux con-

No. of dye	Dye	Absorption maximum (mμ)	Melting point (decomp.)	Yield (%)	N Found (%)	Empirical formula	N Calculated (%)	Absorption maximum of the corresponding amino-substituted styril (mμ)
I	(structure) $-CH=CH-\langle \rangle-NHCOCH_3$, ClO_4^-, phenyl-quinolinium	438	298°	65	5.90, 5.96	$C_{25}H_{21}O_5N_2Cl$	6.02	536
II	(structure) $-CH=CH-\langle \rangle-NHCOCH_3$, ClO_4^-, H_3C-, CH_3	436	280	62	5.44, 5.52	$C_{27}H_{25}O_5N_2Cl$	5.68	530
III	(structure) $-CH=CH-\langle \rangle-NHCOCH_3$, J^-, phenyl	444	328	50	4.98, 5.08	$C_{29}H_{23}ON_2J$	5.16	530

No. of dye	Dye	Absorption maximum (mμ)	Melting point (decomp.)	Yield (%)	N Found (%)	Empirical formula	N Calculated (%)	Absorption maximum of the corresponding amino-substituted styryl (mμ)
IV		440	332	55	4.85, 4.94	$C_{30}H_{25}ON_2I$	5.03	530
V		440	238	54	4.78, 4.82	$C_{33}H_{25}O_5N_2Cl$	4.95	530
VI		447	230	67	4.96, 4.88	$C_{29}H_{23}O_5N_2Cl$	5.16	544
VII		442	224	63	5.08, 5.12	$C_{30}H_{25}O_5N_2Cl$	5.29	540

denser at 120° for 40 minutes. The reaction mass was then poured into water. The precipitated dye was crystallized from alcohol; lustrous yellow crystals.

(1-p-Tolyl-6-methyl quinolyl-2)-p-acetyl aminostyril perchlorate (II). A mixture of 0.3 g of 1-p-tolyl-6-methyl quinaldinium perchlorate, 0.15 g of p-acetyl aminobenzaldehyde and 1.5 ml of pyridine was heated to boiling for 45 minutes. The dye was precipitated with water and was crystallized from alcohol; lustrous orange crystals.

(1-Phenyl-5,6-benzoquinolyl-2)-p-acetyl aminostyril iodide (III). A quantity of 0.5 g of benzoquinaldinium phenyl iodide, 0.2 g of p-acetyl aminobenzaldehyde and 3 ml of pyridine were heated for 50 minutes at 120°. The dye was precipitated with water, filtered and crystallized from aqueous alcohol; orange crystals.

(1-p-Tolyl-5,6-benzoquinolyl-2)-p-acetyl aminostyril iodide (IV). We heated 0.2 g of 1-p-tolyl-5,6-benzo-quinaldinium iodide, 0.1 g of p-acetyl aminobenzaldehyde and 1 ml of pyridine for 50 minutes, the mixture being boiled gently. Recrystallization of the styril from alcohol gave orange crystals.

(1-ß-Naphthyl-5,6-benzoquinolyl-2)-p-acetyl aminostyril perchlorate (V). A mixture of 0.2 g of 1-ß-naphthyl-5,6-benzoquinaldinium, 0.07 g of p-acetyl aminobenzaldehyde and 1 ml of pyridine was boiled for 40 minutes. The styril was precipitated with water, it was washed well and was crystallized from aqueous alcohol; brown crystals.

(1-α-Naphthylquinolyl-2)-p-acetyl aminostyril perchlorate (VI). We heated 0.54 g of 1-α-naphthyl quinaldinium perchlorate, 0.26 g of p-acetyl aminobenzaldehyde and 0.5 ml of pyridine for 60 minutes, the mixture being boiled gently. The dye obtained was crystallized from aqueous alcohol; dark-brown powder.

(1-α-Naphthyl-6-methylquinolyl-2)-p-acetyl aminostyril perchlorate (VII). A quantity of 0.2 g of 1-α-naphthyl-6-methyl quinaldinium perchlorate, 0.05 g of p-acetyl aminobenzaldehyde and 1.5 ml of pyridine were heated to boiling on a paraffin bath for 45 minutes. The dye formed was precipitated with water and crystallized from aqueous alcohol (1 : 1); it was a finely crystalline powder.

SUMMARY

1. Seven new dyes—styrils—were obtained by condensing N-arylquinaldinium quaternary salts with p-acetyl aminobenzaldehyde, and were characterized.

2. The absorption spectra of these styrils in the visible part of the spectrum were determined; it was shown that acylation of the amino group in the styrenes gives a hypsochromic displacement of the absorption maximum by ~100 mμ .

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THE BECKMANN REARRANGEMENT OF OXIMES
OF THIOPHENOCYCLOALKANONES

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The Beckmann rearrangement of oximes of cyclic ketones has been used for about 20 years for the production of lactams of aliphatic amino acids, which can be employed for obtaining polyamide fibers. The attention of investigators has recently been attracted by polyamides containing cyclic (particularly aromatic) groups in the chain [1-7]. In a number of cases it is noted that these polyamides are characterized by a high melting point, a relatively high thermal stability and other valuable properties.

For this reason, lactams of acids of ω-(3-aminothienyl-2)-alkane with the general formula (I), containing a seven or eight-membered ring combined with a thiophene ring might be of interest for an investigation of hydrolytic polymerization.

$R = H$ or alkyl
$n = 3$ or 4.

(I)
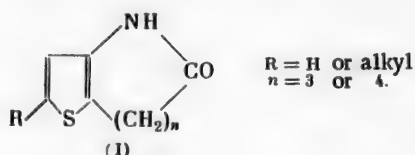
The Beckmann rearrangment of thiophenocycloalkanone oximes, which could also be employed for the synthesis of the little-investigated amino acids of the thiophene series, is a convenient method for obtaining lactams of (I).

In addition, it appeared quite possible to effect hydrogenolysis of these lactams using Raney nickel and thus obtain C-substituted lactams of aliphatic amino acids, which are of independent interest for the investigation of polymerization.

Broadly speaking, the result of the rearrangement of thiophenylcycloalkanone oximes of formula (II) may be lactams of two types (I) and (III).

(II)   (III)
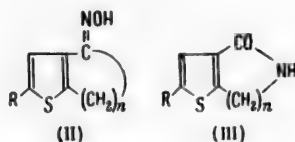
However, on the basis of the general laws of the Beckmann rearrangement of ketoximes [8], and taking into account the results of experiments on the isomerization of benzocycloalkanone oximes [9], leading to the formation of lactams of only one structure, it must be expected that rearrangement of thiophenocycloalkanone oximes will give only lactams of structure (I), the NH group of which is combined with the thiophene ring.

Experiment confirmed our assumption. By the action of benzene sulfonyl chloride on oximes of thiophenocycloheptanones (II, n = 4) we obtained lactams which, judging by their properties (see below), have structure (IV), not (V).

(IV)   (V)
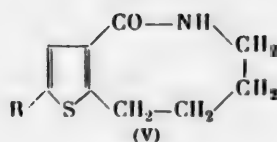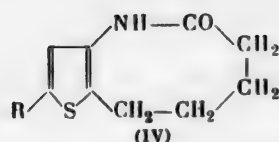
By the action of benzene sulfonyl chloride on the oxime of 2',3'-thipheno-1,2-cyclohexanone (II, R = H, n = 3) we obtained benzene sulfonate oxime, which when heated with a solution of potassium acetate gave the lactam of γ-(3-aminothienyl-2)-butyric acid (I, R = H, n = 3). [*]

Since, in all cases we obtained substances with a distinct melting point, it may be concluded that they were individual lactams and not mixtures of isomeric lactams.

To establish the structure of the substances obtained, we used the method employed by Huisgen and his co-workers [9] for investigating the structure of lactams containing a benzene ring. The method is based on the ability of an amino group, combined with an aromatic (in this case, thiophene) ring, to undergo a diazotization reaction, with formation of an azo dye (VII) when the solution of the diazo compound obtained reacts with β-naphthol.

For our compounds, this method of proof is illustrated by the system.
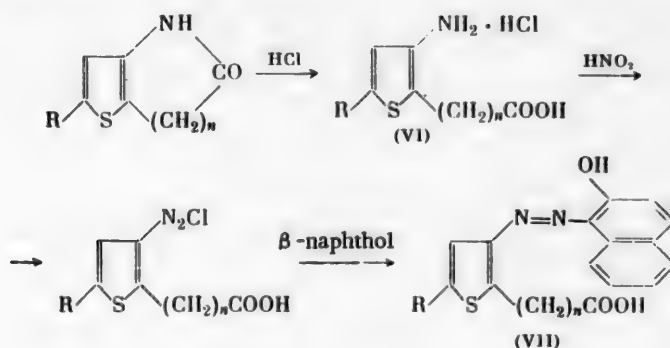
In all the cases investigated, azo dyes (VII) were obtained with yields of more than 90%. From this it follows that the predominant, or, more probably, the only lactams formed by the Beckmann rearrangement of oximes of thiophenocycloalkanones are lactams with structure (I), with an NH group joined to a thiophene ring.

By rearrangement of the corresponding oximes we obtained the lactam of γ-(3-aminothienyl-2)-butyric acid (I, R = H, n = 3), the lactam of δ-(3-aminothienyl-2)-valeric acid (I, R = H, n = 4), the lactam of δ-(3-amino-5-methylthienyl-2)-valeric acid (I, R = CH₃, n = 4) and the lactam of β-methyl-δ-(3-aminothienyl-2)-valeric acid (VIII).

(VIII)
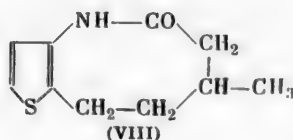
The oximes necessary for the rearrangement experiments were synthesized as follows.

R = H or CH₃,
R' = CH₃ or C₂H₅,
n = 3 or 4.

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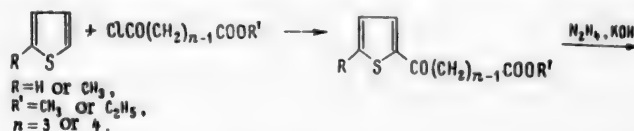
[*] Attempts to obtain this lactam by the Schmidt method of reacting 2',3'-thiopheno-1,2-cyclohexanone-3 with hydrazoic acid in the presence of polyphosphoric acid were not successful (the initial ketone was obtained).

$$\longrightarrow \quad R{-}[\text{thiophene}]{-}S{-}(CH_2)_n COOH \xrightarrow{SOCl_2} R{-}[\text{thiophene}]{-}S{-}(CH_2)_m COCl \xrightarrow{SnCl_4} R{-}[\text{thiophene}]{-}S{-}(CH_2)_n \overset{O}{\underset{\|}{C}} \xrightarrow{NH_2OH} R{-}[\text{thiophene}]{-}S{-}(CH_2)_n \overset{NOH}{\underset{\|}{C}}$$

$$\text{(X)} \qquad\qquad \text{(XI)} \qquad\qquad \text{(XII)} \qquad\qquad \text{(II)}$$
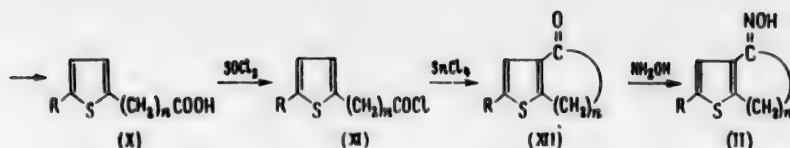
The esters of keto acids (IX) were obtained by the familiar method of reacting acyl chlorides of polyesters of aliphatic dicarboxylic acids with thiophene or methyl thiophene in the presence of stannic chloride. When the keto groups were reduced by hydrazine by a modification of the Kischner method, saponification of the ester group took place simultaneously with the formation of thienyl alkane acids (X), which were converted by thionyl chloride to the corresponding acyl chlorides (XI). Intramolecular cyclization of the acyl chlorides (XI) was carried out by the method in [10]; the yield of thiophenocycloalkanones (XII) was 80-90 %. Oximes (II) were obtained by reacting ketones (XII) with hydroxylamine in alkali.

By continued heating with hydrochloric acid, lactams (I) were converted to the hydrochlorides of amino acids (VI). When solutions of (VI) were reacted with the theoretical amount of sodium acetate, free amino acids (XIII) were precipitated; these were unstable compounds which darkened on heating.

$$R{-}[\text{thiophene}]\overset{NH_2}{\underset{S}{\quad}}{-}(CH_2)_n COOH$$

$$\text{(XIII)}$$
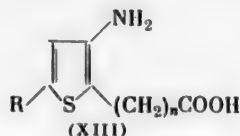
EXPERIMENTAL

Preparation of esters of ω-(tenoyl-2)-alkane acids. The methyl ester of β-(tenoyl-2)-propionic acid (IX, R = H, R' = CH$_3$, n = 3), the ethyl ester of γ-(tenoyl-2)-butyric acid (IX, R = H, R' = C$_2$H$_5$, n = 4) and the ethyl ester of β-methyl-γ-(tenoyl-2)-butyric acid (A)

$$[\text{thiophene}]{-}S{-}COCH_2CHCH_2COOC_2H_5$$
$$\text{(A)} \qquad \underset{CH_3}{\mid}$$
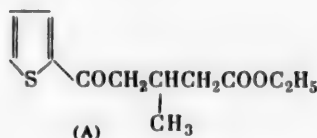
were synthesized by a known method [11] from thiophene and the acyl chlorides of polyesters of dicarboxylic acids. The condensation of methyl thiophene with carbomethoxybutyl chloride was carried out in a similar way.

A solution of 95 ml of stannic chloride in 90 ml of benzene was added dropwise with stirring to a solution of 84 g of methyl thiophene and 135 g of carbomethoxybutyl chloride in 550 ml of benzene at 0-5°. The reaction mass was stirred for 2 hours at room temperature and was then decomposed with dilute (1 : 10) hydrochloric acid. The organic layer was separated, washed with dilute hydrochloric acid, a saturated solution of sodium chloride, and a sodium bicarbonate solution and was then dried with magnesium sulfate. The solvent was distilled from the benzene solution, and the residue was distilled under vacuum. We obtained 162.7 g of the methyl ester of γ-(5-methyl-tenoyl-2)-butyric acid (IX, R = CH$_3$, R' = CH$_3$, n = 4). The yield of the ester was 87%, the b.p. was 186-187° at 10 mm. The distilled substance melted at 35-37.5°. After it had been recrystallized twice from hexane the substance had an m.p. of 41-42.5°.

Found %: C 58.04, 58.26; H 6.37, 6.22; S 14.15, 14.15. C$_{11}$H$_{14}$O$_3$S. Calculated %: S 58.38; H 6.24; S 14.17.

Preparation of ω-(thienyl-2)-alkane acids. By reduction with hydrazine hydrate by a modified Kischner method [11], the esters of ω-(tenoyl-2)-alkane acids (IX) were converted to the corresponding ω-(thienyl-2)-alkane acids: γ-(thienyl-2)-butyric acid (X, R = H, n = 3), δ-(thienyl-2)-valeric acid (X, R = H, n = 4) and β-methyl-δ-(thienyl-2)-valeric acid (B).

$$\text{(B)} \quad \underset{\underset{\displaystyle CH_3}{|}}{\text{S} \quad CH_2CH_2CHCH_2COOH}$$
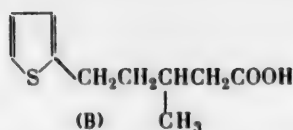
The methyl ester of γ-(5-methyl-tenoyl-2)-butyric acid (IX, R = CH$_3$, R' = CH$_3$, n = 4) was reduced by the same method.

A mixture of 154.6 g of the methyl ester of γ-(5-methyltenoyl-2)-butyric acid, 95 ml of hydrazine hydrate, 129 g of caustic potash and 920 ml of diethylene glycol was boiled for 2 hours with a reflux condenser. The water and excess hydrazine distilled when the temperature in the flask reached about 200°. The remaining mixture was boiled for 4 hours. The cooled filtered solution was diluted with 1.5 liters of water and acidified to congo with concentrated hydrochloric acid. The precipitate was filtered, washed repeatedly with water and dried. We obtained 120 g (yield 88%) of δ-(5-methylthienyl-2)-valeric acid (X, R = CH$_3$, n = 4) with an m.p. of 54-57°. According to [12] the m.p. is 57.5°.

Preparation of the acyl chlorides of ω-(thienyl-2)-alkane acids. By reacting thionyl chloride with solutions of ω-(thienyl-2)-alkane acids (X) in absolute ether, as proposed in [10], we obtained acyl chlorides of γ-(thienyl-2)-butyric (XI, R = H, n = 3), δ-(thienyl-2)-valeric (XI, R = H, n = 4) [10] and δ-(5-methylthienyl-2)-valeric (XI, R = = CH$_3$, n = 4) [12] acids, and the previously unknown acyl chloride of β-methyl-δ-(thienyl-2)-valeric acid.

A quantity of 55 g of thionyl chloride was added to a solution of 85.7 g of β-methyl-δ-(thienyl-2)-valeric acid in 210 ml of absolute ether. The solution was left for 16 hours at room temperature and was then boiled for 1 hour with a reflux condenser. The ether and excess thionyl chloride was distilled from the mixture. The residue was distilled under vacuum. We obtained 77.4 g of the acyl chloride of β-methyl-δ-(thienyl-2)-valeric acid; the b.p. was 122-123° at ~2 mm. The yield of the product was 83%.

Preparation of thiophenocycloalkanones by intramolecular acylation of acyl chlorides of ω-(thienyl-2)-alkane acids. 2',3'-Thiopheno-1,2-cyclohexanone-3 (XII, R = H, n = 3) and 2',3'-thiopheno-1,2-cycloheptanone-3 (XII, R = H, n = 4) [10], 5'-methyl-2',3'-thiopheno-1,2-cycloheptanone-3 (XII, R = CH$_3$, n = 4)[12], and the previously unknown 5-methyl-2',3'-thiopheno-1,2-cycloheptanone-3 (C) were synthesized by intramolecular acylation of the acyl chlorides of ω-(thienyl-2)-alkane acids by the method given in [10].

$$\text{(C)}$$
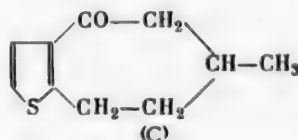
A solution of 17.8 g of the acyl chloride of β-methyl-δ-(thienyl-2)-valeric acid was added dropwise at 3-5° with stirring (for 6 hours) to a solution of 45 ml of stannic chloride in 750 ml of benzene. The reaction mass was stirred for 2 hours and was then decomposed with 200 ml of dilute (1 : 10) hydrochloric acid, which was added gradually at a temperature below 15°. After the mixture had been stirred for 1 hour at room temperature, all the precipitate passed into solution. The organic layer was separated, washed with dilute hydrochloric acid, a sodium chloride solution, a sodium carbonate solution and then with salt again. The benzene was driven off and the residue was distilled under vacuum. We obtained 12.6 g (85%) of 5-methyl-2',3'-thiophen-1,2-cycloheptanone-3 with a b.p. of 112-113° at 1.2 mm, n$_D^{20}$ 1.5705, d$_4^{20}$ 1.1499.

Found %: C 66.50, 66.64; H 6.65, 6.67; S 17.84, 17.67. C$_{10}$H$_{12}$OS. Calculated %: C 66.62; H 6.71; S 17.79.

After recrystallization from alcohol, the semicarbazone of this ketone melted at 166-167°.

Found %: C 55.21, 55.40; H 6.29, 6.16; S 13.18, 13.29. C$_{11}$H$_{17}$ON$_3$S. Calculated %: C 55.67; H 6.37; S 13.51.

Preparation of oximes of thiophenocycloalkanones. The oxime of 5-methyl-2',3'-thiopheno-1,2-cyclohep-tanone-3. The oxime was obtained by boiling a mixture of 15.5 g of the ketone, 17.9 g of hydroxylamine hydro-chloride, 21.6 g of caustic potash, 70 ml of alcohol and 100 ml of water for 5 hours, with dilution of the reaction

TABLE 1

Name of substance	Melting point	Yield (%)	Literature data	
			melting point	lit. ref.
Oxime of 2',3'-thiophenol-1,2-cyclohexanol-3 (II, R = H, n = 3)	130—131°	76 {	128—129° 131—132	[13] [14]
Oxime of 2',3'-thiopheno-1,2-cycloheptanone-3 (II, R = H, n = 4)	102—103	94	100—101	[15]
Oxime of 5'-methyl-2',3'-thiopheno-1,2-cycloheptanone-3 (II, R = CH₃, n = 5) •	123—124	77	—	—

• Found %: C 61.23, 61.30; H 6.86, 6.81; S 16.26, 16.37. $C_{10}H_{13}ONS$. Calculated %: C 61.50; H 6.71; S 16.42.

TABLE 2

Name of substance	Melting point	Yield (%)	Empirical formula	% C		% H		% S	
				found	calculated	found	calculated	found	calculated
Lactam of δ-(3-aminothienyl-2)-valeric acid (IV, R = H)	157—158°	83	$C_9H_{11}ONS$	59.84, 59.81	59.63	6.02, 6.08	6.12	17.29, 17.29	17.69
Lactam of δ-(3-amino-5-methyl-thienyl-2)-valeric acid (IV, R = CH₃)	191—192	96	$C_{10}H_{13}ONS$	61.45, 61.47	61.50	6.78, 6.97	6.71	16.46, 16.30	16.42

mass with 50 ml of water, cooling of the solution, followed by separation of the precipitate. We obtained 15.0 g of oxime, the m.p. was 68-71°. The yield of the unpurified substance was 90%. After recrystallization from hexane, the oxime melted at 69-71°.

Found %: C 61.42, 61.59; H 6.50, 6.51; S 16.28, 16.22. $C_{10}H_{13}ONS$. Calculated %: C 61.50; H 6.71; S 16.42.

The oximes of the other thiophenocycloalkanones were obtained in a similar way. Their properties are given in Table 1.

Preparation of lactams by the Beckmann rearrangement of oximes of thiophenocycloalkanones. The Beckmann rearrangement of oximes (II) to lactams (I) was carried out by the action of benzene sulfonyl chloride in pyridine; during this process, oximes containing a seven-membered ring underwent rearrangement immediately, while the oxime of thiophenocyclohexanone (II, R = H, n = 3) formed the benzene sulfonate; this gave a lactam when heated with a solution of potassium acetate. The same lactam was obtained, but with a lower yield, by rearrangement of the oxime (II, R = H, n = 3) by means of polyphosphoric acid.

Benzene sulfonate of 2',3'-thiopheno-1,2-cyclohexanone-3-oxime (D).

(D)
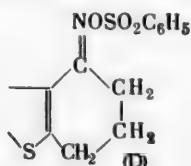
A solution of 12.5 ml of benzene sulfonyl chloride in 25 ml of pyridine was added in one operation to a solution of 12.5 g of the oxime in 125 ml of purified pyridine. The mixture was left for 24 hours at room temperature (the flask was placed in a water bath); it was poured into 200 ml of 4 N hydrochloric acid saturated with sodium chloride and was then made acid to congo by the addition of concentrated hydrochloric acid. The crystals were filtered, washed repeatedly with water and dried in a vacuum desiccator. We obtained 21.9 g of the benzene sulfonate of the oxime (yield 95%); the m.p. was 122-124°. After recrystallization from a mixture of ethyl acetate and hexane, the product had an m.p. of 123-124° (with decomp.).

Found %: C 54.98, 54.69; H 4.44, 4.46; S 20.70, 20.60. $C_{14}H_{13}O_3NS_2$. Calculated %: C 54.70; H 4.26; S 20.86.

Lactam of γ-(3-aminothienyl-2)-butyric acid (I, R = H, n = 3). A quantity of 21.9 g of the benzene sulfonate of 2',3'-thipheno-1,2-cyclohexanone-3-oxime was added to a solution of 110 g of anhydrous potassium acetate in 765 ml of water and 220 ml of alcohol. The mixture was boiled for 22 hours on the water bath, the alcohol was distilled and the residue was treated with activated carbon. After the crystals precipitated when the solution cooled had been filtered and they were washed with water. The weight of the dried yellowish lactam was 8.6 g (yield 72%), the m.p. was 132-135°. After recrystallization from dilute alcohol (with addition of activated carbon), a colorless lactam with an m.p. of 135° was obtained.

Found %: C 57.11, 57.36; H 5.46, 5.42; N 8.14, 8.40; S 18.87, 19.00. C_8H_9ONS. Calculated %: C 57.45; H 5.42; N 8.38; S 19.18.

Lactam of β-methyl-δ-(3-aminothienyl-2)-valeric acid (E)

(E)
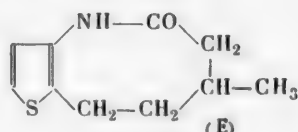
A solution of 12 ml of benzene sulfonyl chloride in 20 ml of pyridine was added to a solution of 15.7 g of the oxime of 5-methyl-2',3'-thiopheno-1,2-cycloheptanone-3 in 120 ml of pyridine. The mixture was left for 16 hours in a bath, the water in which was at room temperature. The solution was poured into 350 ml of 4 N hydrochloric acid saturated with salt. The mixture was acidified to congo with hydrochloric acid. The solution was cooled with ice. The crystals were filtered, washed with water and dried. We obtained 11.8 g (75%) of the unpurified lactam with an m.p. of 141-144.5°. Lactam with an m.p. of 148-149° was obtained after treatment with activated carbon and recrystallization from a mixture of toluene and heptane.

Found %: C 61.17, 61.23; H 6.54, 6.62; S 16.09, 16.08. $C_{10}H_{13}ONS$. Calculated %: C 61.50; H 6.71; S 16.42.

The rearrangement of other oximes was carried out in a similar way. The properties of the lactams obtained are given in Table 2.

Preparation of the hydrochlorides of amino acids by hydrolysis of lactams. The hydrochlorides of amino acids (VI) were obtained by brief boiling of the corresponding lactams with dilute (1 : 1) hydrochloric acid (about 15 ml of acid per gram of lactam). The solutions obtained were decolorized with activated carbon and cooled. The hydrochlorides were filtered and dried. They were purified by recrystallization from dilute (1 : 1) hydrochloric acid with addition of activated carbon. All of them melted with decomposition and turned yellow fairly rapidly. The apparatus in which the melting points were determined was subjected to a preliminary heating. The Cl' content in all the hydrochlorides was determined by the Volhardt method.

Hydrochloride of β-methyl-δ-(3-aminothienyl-2)-valeric acid (F)
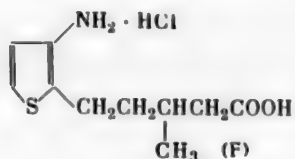
was obtained with a 79% yield; the m.p. was 170-172°.

Found %: C 48.09, 48.17; H 6.46, 6.41; Cl' 14.19, 14.45; N 5.60, 5.53. $C_{10}H_{16}O_2NClS$. Calculated %: C 48.08; H 4.46; Cl' 14.20; N 5.61.

TABLE 3

Name of the substance	Melting point	Yield (%)	Empirical formula	% C found	% C calculated	% H found	% H calculated	% Cl found	% Cl calculated	% N found	% N calculated	% S found	% S calculated
γ-(3-Aminothienyl-2)-butyric acid (XIII, R = H, n = 3)	120°	92	$C_8H_{11}O_2NS$	51.98, 52.05	51.87	6.30, 6.26	5.99	—	—	7.66, 7.66	7.56	17.13, 17.00	17.31
Hydrochloride (VI, R = H, n = 3)	214—215	94	$C_8H_{12}O_2NClS$	43.13, 43.28	43.44	5.44, 5.37	5.46	15.96, 15.76	15.99	6.47, 6.62	6.32	—	—
Benzoyl derivative	155.5—156.5	—	$C_{15}H_{15}O_3NS$	—	—	—	—	—	—	5.03, 4.93	4.84	—	—
Azo dye (VII, R = H, n = 3)	140.5—141.5	93	$C_{18}H_{16}O_3N_2S$	63.40, 63.22	63.51	4.74, 4.73	4.74	—	—	—	—	9.28, 9.21	9.42
δ-(3-Aminothienyl-2)-valeric acid (XII, R = H, n = 4)	116—117	92	$C_9H_{13}O_2NS$	54.24, 54.10	54.24	6.48, 6.63	6.57	—	—	—	—	15.94, 15.67	16.09
Hydrochloride (VI, R = H, n = 3)	191—192	85	$C_9H_{14}O_2NClS$	45.63, 45.57	45.85	5.82, 5.71	5.99	14.86, 14.85	15.04	5.89, 6.07	5.94	—	—
Benzoyl derivative	151.5—152.5	—	$C_{16}H_{17}O_3NS$	—	—	—	—	—	—	4.76, 4.87	4.62	—	—
Azo dye (VII, R = H, n = 3)	158.5—159.5	93	$C_{19}H_{18}O_3N_2S$	64.19, 64.38	64.38	4.98, 5.23	5.12	—	—	—	—	8.85, 8.76	9.05
δ-(3-Amino-5-methylthienyl-2)-valeric acid (XIII, R = CH₃, n = 4)	128—129	97	$C_{10}H_{15}O_2NS$	56.12, 56.10	56.31	7.33, 7.06	7.09	—	—	—	—	14.98, 15.10	15.03
Hydrochloride (VI, R = H, n = 3)	202.5—203.5	88	$C_{10}H_{16}O_2NClS$	47.92, 48.17	48.08	6.40, 6.53	6.46	13.88, 13.95	14.20	5.27, 5.46	5.61	—	—
Benzoyl derivative	159.5—161	—	$C_{17}H_{19}O_3NS$	—	—	—	—	—	—	4.34, 4.55	4.41	—	—
Azo dye (VII, R = H, n = 3)	170	97	$C_{20}H_{20}O_3N_2S$	65.16, 65.21	65.19	5.63, 5.62	5.47	—	—	—	—	8.71, 8.55	8.71

The properties of the other hydrochlorides are given in Table 3.

Preparation of the free amino acids. Amino acids (XIII) were obtained by the action of the theoretical amounts of sodium carbonate on solutions of their hydrochlorides in water. The precipitated amino acids were washed free from salt, dried and recrystallized from hot (70°) water (appreciable decomposition of the acids occurs if they are heated to higher temperatures); they all melt with decomposition.

β-Methyl-δ-(3-aminothienyl-2)-valeric acid has an m.p. of 74-76°; the yield is 52%. When this amino acid was precipitated by addition of an equimolar amount of sodium carbonate to its hydrochloride, it was obtained as an oil, which rapidly crystallized.

Found %: C 56.13, 56.28; H 7.22, 7.10; S 14.87, 14.99. $C_{10}H_{15}O_2NS$. Calculated %: C 56.31; H 7.09; S 15.03.

The benzoyl derivative melted at 134-135°.

Found %: N 4.42, 4.44. $C_{17}H_{19}O_3NS$. Calculated %: N 4.41.

The properties of the other amino acids and their benzoyl derivatives are given in Table 3.

Preparation of azo dyes from the amino acid hydrochlorides. The hydrochlorides of amino acids (VI) were diazotized and the diazonium salts were coupled with β-naphthol. All the dyes synthesized were varying shades of red.

The azo dye from the hydrochloride of β-methyl-δ-(3-aminothienyl-2)-valeric acid (K).
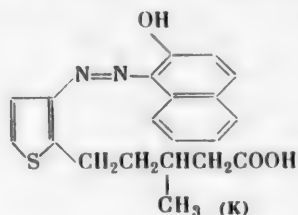
A volume of 2.5 ml of concentrated hydrochloric acid was added to a solution of 1.5 g of β-methyl-δ-(3-aminothienyl-2)-valeric acid hydrochloride in 50 ml of water; a saturated solution of sodium nitrite at 2-3° was added until a steady positive reaction was obtained with starch iodide paper. The cold reaction mixture was neutralized to congo with a saturated solution of sodium acetate, and a solution of 0.87 g of β-naphthol in 19 ml of 10% caustic soda was then added. A copious red precipitate formed immediately. The mass was shaken periodically for 1 hour and was then acidified with concentrated hydrochloric acid. The precipitate was filtered, washed repeatedly with water and dried in a vacuum desiccator, we obtained 2.12 g of the azo dye; the yield was 96%. After it had been recrystallized twice from alcohol, the substance melted at 155-156°.

Found %: C 64.90, 64.98; H 5.17, 5.42; S 8.78, 8.65. $C_{20}H_{20}O_3N_2S$. Calculated %: C 65.19; H 5.47; S 8.71.

The properties of the other dyes synthesized from the amino acid hydrochlorides are given in Table 3.

A further proof of the fact that the lactams formed by the rearrangement of oximes (II) are individual substances is the high yield of the dyes obtained directly from the lactams (the lactams were saponified, while the amino acid hydrochlorides were not precipitated from the solution and were not purified, but were diazotized immediately).

SUMMARY

1. By the Beckmann rearrangement of the oximes of 2',3'-thiopheno-1,2-cyclohexanone-3, 2',3'-thiopheno-1,2-cycloheptanone-3, 5'-methyl-2',3'-thiopheno-1,2-cycloheptanone-3 and 5-methyl-2',3'-thiopheno-1,2-cyclo-heptanone-3, the corresponding lactams of γ-(3-aminothienyl-2)-butyric, δ-(3-aminothienyl-2)-valeric, δ-(3-amino-5-methylthienyl-2)-valeric and β-methyl-δ-(3-aminothienyl-2)-valeric acids were obtained.

2. That the lactams were derivatives of amino acids of the aromatic series with the amino group in the ring was proven by saponification, diazotization of the amino acid hydrochlorides obtained, and coupling of the diazo compounds with β-naphthol to give the corresponding azo dyes.

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THE REACTION OF SULFARSAZENE WITH LEAD

A. M. Lukin and G. S. Petrova

Many diazoamino compounds (triazenes) are able to react with metal ions [1-14]; this reaction is usually accompanied by a change in color and is connected with the formation either of salts of the triazene group (with Na, Hg, Ag, Cu, Ni) [1, 5, 6, 8], or of compounds of an adsorptive character (with Cd and Mg) [2-4, 10, 12, 13]. It should be noted in this connection that only a few triazenes that were studied in the papers mentioned contain acid groups (HSO_3, $H_2As_8O_3$) in the aromatic rings; in their ability to react with cations they do not differ from analogous compounds that do not contain these groups [2, 4]. We observed a similar situation on comparing 4°-nitrobenzene-1° 4-diazoamino-1, 1'-azobenzene (1), which forms adsorption reaction products with Cd [10, 13] with its monosulfonic acid (II) [15].

$$O_2N-\langle\!\rangle-N{=}N{-}NH-\langle\!\rangle-N{=}N{-}\langle\!\rangle-X_1$$

X = X₁ = H (I);   X = H; X₁ = SO₃H (II);
X = SO₃H; X₁ = H (III);   X = AsO₃H₂; X₁ = SO₃H (IV).
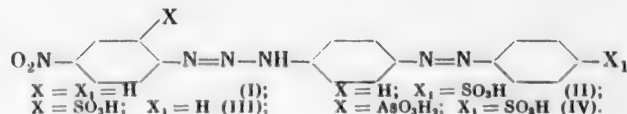
At the same time it was determined that compounds (III) and (IV), obtained for the first time, in contrast to (I) and (II), give color reactions with new cations, and in particular with lead [15, 16]. It was of interest to seek the reason for this difference and to find what interaction is fundamentally responsible for this new color reaction.

Compound (IV) was selected as a special object for study; it is of practical interest and is known under the name of "sulfarsazene" ("Plyumbom IREA") [17].

First of all we succeeded in preparing the reaction product of sulfarsazene with lead [in the presence of an excess of lead (V)]. Analysis showed that it corresponds to a double lead-sodium salt, and both acid groups of the sulfarsazene showed an ability to react with lead.* Since compound (II) also forms a lead salt (VI), without color change, the color reaction of sulfarsazene with lead must be caused by the interaction of the latter either with one arsonic group or with arsonic and triazene groups simultaneously. Compound (VII), which was synthesized for the purpose of solving this problem, does not give a color reaction with the lead ion.

$$AsO_3H_2$$
$$O_2N-\langle\!\rangle-N{=}N-NH-\langle\!\rangle-N{=}N-\langle\!\rangle-SO_3Na$$

(VII)
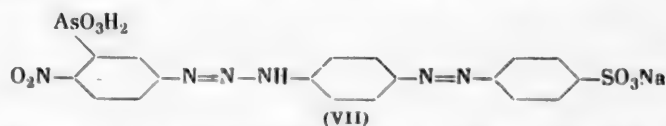
Thus an essential condition for this phenomenon appears to be the ortho position of the arsonic and triazene groups. At the same time it was determined that substitution of the hydrogen of the imino group by the methyl results in a complete loss of ability to give a color reaction with a lead ion.**

At the same time compound (VIII) forms a reaction product with lead (IX), which was separated, and from its composition was shown to be a product roughly analogous to that formed by the reaction of sulfarsazene with lead.

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* The composition of the reaction product of sulfarsazene with lead in solution, determined by the Zhob-Ostromyslenskii method, is equal to 1 g-atom of lead, 1 g-mole of sulfarsazene.
** Data showing the interaction of these compounds with lead, from the point of view of changes in the color of solutions, are given in the table in the Experimental Section.
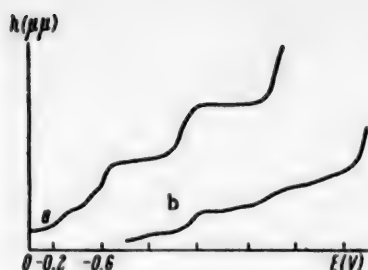
Fig. 1. Reduction curves. a) Sulfarsazene; b) reaction product of sulfarsazene with lead.
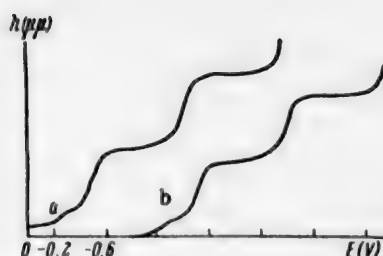
Fig. 2. Reduction curves. a) Compound (VIII); b) reaction product of compound (VIII) with lead.

$O_2N-\langle\ \rangle-N=N-N-\langle\ \rangle-N=N-\langle\ \rangle-SO_3Na$

with AsO$_3$H$_2$ and CH$_3$ substituents (VIII)
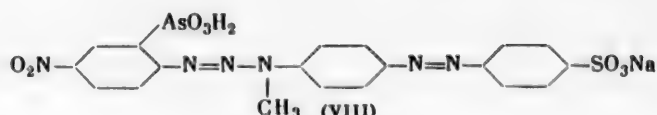
In order to clarify the difference in the properties of reaction products of compound (IV) and compound (VIII) with a lead ion, polarographic methods were used.

Figures 1 and 2 show the polarograms of compounds (IV) and (VIII) before and after they added a lead ion. In the case of sulfarsazene the introduction of a lead ion leads to a sharp decrease in the height of the reduction waves owing to a decrease in the concentration of sulfarsazene in the solution, while in the case of the N-methyl derivative the reduction curve did not change after introduction of the lead ion. In the latter case, apparently, a normal salt is formed, while sulfarsazene forms a more stable reaction product in which lead is joined to some polarographically active groups; one can in all probability assume that a six-membered ring (X) is formed which includes an atom of lead and two salt-forming groups in ortho positions— the arsonic and the triazene (possibly supplemented by coordination bonds). All the preceding data are in agreement with this.

(X)   (XI)

In every case it is apparent that the ortho-arsonotriazene grouping (XI), in its ability to form stable metallic salts, differs essentially from the azo group with one substituent in the ortho position (it is well known that azo dyes, containing the latter, form unstable metallic salts) [18, 19]. The new grouping may rather be compared with an azo group with two substituents in o,6-positions [18-20]; in the example given the imine group is the second salt-forming group.

All this gives evidence that the o-arsonotriazene grouping predetermines the color reaction of sulfarsazene with a cation of lead. But it would be erroneous to assume that the presence of this grouping only assures a sharp displacement of the absorption maximum of sulfarsazene in its reaction with lead; on examination of the simplest compound (XII) that also contains grouping (XI) it is found that although it also changes color on reaction with lead, it does so much less than sulfarsazene.

(XII)
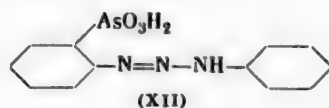
Consequently the presence of nitro and azo groups for the color reaction of sulfarsazene with lead is essential; however the role of these groups will be clarified in a separate paper.

EXPERIMENTAL*

The Reaction Product of Sulfarsazene** with Lead (V)

$$\left(O_2N-\langle\rangle-\overset{\overset{O\;\;\bar{O}}{As\diagdown O}}{\underset{N-N=N-\langle\rangle-N=N-\langle\rangle-S\bar{O}_3}{\overset{Pb}{|}}}\right)_3 Pb^{++}Na^+H_3^+\cdot 3H_2O$$
(V)
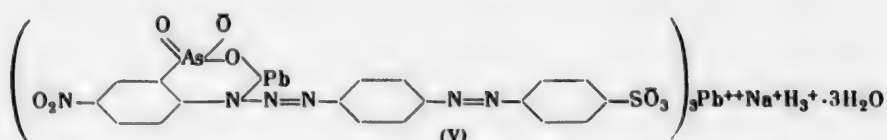
Two grams of lead nitrate (c.p.) were dissolved in 60 ml of water. At the same time 0.6 g of sulfarsazene (the amounts of the reacting substances were calculated on the basis of 1 g-mole of the reagent to 6 g-atoms of lead) were mixed in a small beaker with 10 ml of a 0.5 M solution of borax until the sulfarsazene was as completely dissolved as possible, and then vacuum filtered. The solution obtained was quickly poured, with stirring, into the lead solution which was heated to 85°; during this the temperature fell from 85 to 70°. It was allowed to stand for no more than three minutes, and then the yellow precipitate was quickly filtered off and washed with 400 ml of hot water until lead could no longer be detected in the filtrate. It was dried to constant weight at 70°. 0.6-0.7 g of a light yellow powder consisting of the lead-sodium salt (with water of crystallization) were obtained.

In order to test for the possible precipitation of byproducts containing lead under the conditions described, a blank experiment was run: 2 g of lead nitrate (c.p.) were dissolved in 60 ml of water. 10 ml of an 0.05 M solution of borax were added to the solution which had been heated to 85°. A precipitate began to fall only in the course of 10-20 min; with other ratios of borax and lead and with other conditions identical, precipitation occurs immediately.

Found %: Pb 31.51, 31.79; Na 1.010, 0.98; As 8.610, 8.740; H_2O 1.91. $C_{54}H_{96}O_{24}N_{18}As_3NaPb_4 \cdot 3H_2O$. Calculated %: Pb 32.53; Na 0.90; As 8.82; H_2O 2.12.

The reaction product of 4"-nitrobenzene-1",4-diazoamino-1,1'-azobenzene-4'-sulfonic acid with lead (VI).

$$\left(O_2N-\langle\rangle-N=N-NH-\langle\rangle-N=N-\langle\rangle-S\bar{O}_3\right)_2 Pb^{++}\cdot 2H_2O$$
(VI)
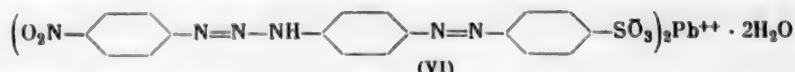
0.45 g of the Na salt of 4"-nitrobenzene-1",4-diazoamino-1,1'-azobenzene-4'-sulfonic acid (II)*** were dissolved in 100 ml of 50% alcohol at 60°. The solution obtained was poured into a solution of 2 g of lead nitrate in 60 ml of water heated to 60°. A yellowish brown material precipitated which after standing for five minutes was filtered off and washed with 500 ml of water and then with 50 ml of alcohol. The material was dried at 60° to constant weight.

Found %: Pb 18.18, 18.01; H_2O 3.02. $C_{36}H_{26}O_{10}N_{12}S_2Pb \cdot 2H_2O$. Calculated %: Pb 18.94; H_2O 3.29.

4"-Nitrobenzene-1",4-diazoamino-1,1'-azobenzene-3"-arsono-4'-sulfonic acid (VII). 1.3 g of p-nitroaniline m-arsonic acid [21] were dissolved in a mixture of 0.2 g of NaOH and 20 ml of water and 0.4 g of sodium nitrate were added to the solution, after which it was poured into a mixture of 3 ml of concentrated hydrochloric acid and 40 ml of water. It was filtered and then 4 g of sodium acetate added at 8-10°. The diazo solution was added at 10° to a solution of 1.5 g of aminoazobenzenesulfonic acid in 60 ml of alcohol and 40 ml of water. A yellow precipitate was formed. This was allowed to stand for half an hour. After drying at 50-60°, 2 g of a yellowish-brown powder was obtained which was rather insoluble in water and alcohol and was a mixture of the mono- and disodium salts.****

Found %: Na 5.34, 5.35; S 5.54, 5.30; As 12.23, 12.06. $C_{18}H_{14}O_9N_6SNaAs + C_{18}H_{13}O_9N_6SNa_2As \cdot 2H_2O$. Calculated %: Na 5.74; S 5.33; As 12.46.

4"-Nitrobenzene-1",4-diazo-N-methylamino-1,1'-azobenzene-2"-arsono-4'-sulfonic acid (VIII). For data on the synthesis and diazotization of p-nitroaniline-o-arsonic acid, see [16].

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*With the assistance of E. E. Balkevich.

**For the synthesis of sulfarsazene see [16].

***For synthesis (II) see [15].

****In view of the instability on drying (above 70°) of compounds of the triazene type (in contrast to their lead salts) we consider the presence of water of crystallization as a condition in showing analogies with the data in the literature [23].

Changes in the Color of Solutions of Triazenes on Reacting with a Lead Ion

Original triazenes	Basic indices of color absorption in $2 \cdot 10^{-5}$ M solutions in 0.05 M borax solutions [*]			
	maximum (in mμ)	molar coefficient of extinction at λ_{max}	maximum (in mμ)	molar coefficient of extinction at λ_{max}
IV	420	42500	500	37500
II	410	39500	410	39500
VII	410	35000	410	34000
VIII	430	44000	430	45000

[*] The measurements were carried out on an SF-4 spectrophotometer.

Monomethylorange was obtained by the combination of diazotized sulfanilic acid with monomethylaniline in a solution of mineral acid [22].

To the diazocompound from 2.6 g of p-nitroaniline-o-arsonic acid at 0° were added 20 ml of a 10% solution of sodium acetate and the solution obtained was added to a solution of 1.5 g of monomethylorange in a mixture of 100 ml of alcohol and 100 ml of water. Within 10-15 min a yellow, crystalline precipitate was formed, which was filtered off, washed with 20 ml of alcohol and dried in air. 3.2 g of a reddish-orange powder, easily soluble in water, were obtained; it was recrystallized from 30 ml of 50% alcohol as the disodium salt.

Found %: Na 7.40, 7.42; As 11.55, 11.46; N 13.23, 13.00. $C_{19}H_{15}O_8N_6Na_2As \cdot H_2O$. Calculated %: Na 7.34; As 11.94; N 13.4.

The reaction product of 4"-nitrobenzene-1",4-diazo-N-methylamino-1,1'-azobenzene-2-arsono-4'-sulfonic acid with lead (IX).

$$\left(O_2N - \underset{\underset{CH_3}{}}{\bigcirc} \overset{\overset{\underset{O}{\|}}{As}\underset{O}{\diagdown} \overline{O}}{} -N=N-\underset{\underset{CH_3}{}}{N} - \bigcirc -N=N- \bigcirc -S\overline{O}_3 \right)_6 Pb_7^{++} Na_4^+ \cdot 6H_2O$$

(IX)
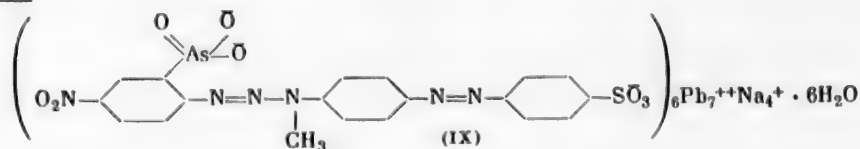
0.62 g of the disodium salt of 4"-nitrobenzene-1",4-diazo-N-methylamino-1,1'-azobenzene-2"-arsono-4'-sulfonic acid were dissolved in 50 ml of water (pH of the solution ~ 4). The solution was filtered and poured, with rapid stirring, into a solution of 1.4 g of lead nitrate (c.p.) in 25 ml of water (the reacting substances were used in the ratio of 1 g-mole : 4 g-atoms of lead). A yellowish-red precipitate was formed immediately. It was filtered off and wahed with 300 ml of warm water, and then with 50 ml of alcohol. It was dried to constant weight at 60-70°. 0.5 g of the lead-sodium salt (with water of crystallization) were obtained; the material was a dark red powder.

Found %: Pb 27.92, 27.98; As 9.06, 9.05; H$_2$O 2.90. $C_{114}H_{84}O_{48}N_{36}S_6Na_4As_6Pb_7 \cdot 6H_2O$. Calculated %: Pb 28.90; As 8.99; H$_2$O 2.20.

Polarographic Measurements [**]

The $1 \cdot 10^{-4}$ M solutions of the original compounds in a 0.05 M solution of borax and alcohol (5 : 1) were prepared. An excess of lead was added to the original solutions in order to prepare solutions of their reaction products with lead. The final concentration of the solution obtained was $1 \cdot 10^{-4}$ M, reagent; $5 \cdot 10^{-4}$ M, lead cation.

An LP-5-A polarograph with a galvanometer with a sensitivity of $1 \cdot 10^{-9}$ amp/mm was used to take the reduction curves; the characteristics of the capillary were — m = 2.4 mg/sec, t = 2.2 sec; and a saturated calomel electrode was used for the anode. All the reduction curves were taken at the same galvanometer sensitivity and under absolutely identical conditions.

[*] With the consultation of N. M. Dyatlova.

SUMMARY

The color reaction of sulfarsazene with lead is caused by the simultaneous participation of a lead ion and of triazene and arsonic groupings in the formation of a colored cyclic salt of the composition: 1 g-atom of lead per 1 g-mole of the reagent.

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STUDIES OF THE ALKOXYSILANES

XVI. THE REACTION OF TETRAALKOXYSILANES WITH KETONES*

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Among the existing methods of synthesizing the acetals of aldehydes and ketones [2-7], one of the simplest and most convenient is the Helferich method [8, 9]. This method,which other authors have used, some with success [10-12] and some unsuccessfully [10, 23], is based on the catalytic reaction of carbonyl-containing compounds with alcohols in the presence of tetraalkoxysilanes.

$$R'R''C = O + 2ROH \underset{}{\overset{H^+}{\rightleftarrows}} R'R''C(OR)_2 + H_2O \tag{1}$$
$$R, R' = Alk; \qquad R'' = H, Alk.$$
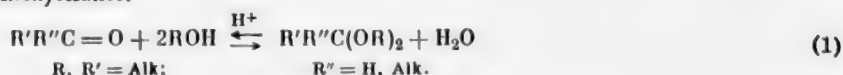
Catalysts for this reaction are the proton acids, their salts, and also ammonium nitrate [9]; those most widely used are hydrogen chloride [8, 9, 11], sulfuric acid [10] and syrup-like (85%) orthophosphoric acid [12].

It is usually considered that tetraalkoxysilanes play an acetalizing role in the reaction, combining with the water of the solution.

$$Si(OR)_4 + nH_2O \overset{H^+}{\rightleftarrows} \frac{1}{m}[(RO)_{4-2n}SiO_n]_m + 2nROH \tag{2}$$
$$n = 0.5-2; \quad m \geqslant 2.$$
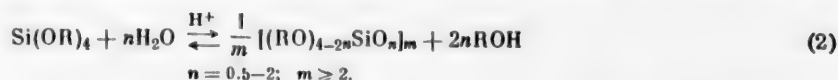
It was not possible to carry out the reaction of tetraalkoxysilanes with aldehydes or ketones in the absence of alcohols (or to substitute other solvents for alcohols [9]). Nevertheless this appeared to be possible in principle, since the summation of equations (1) and (2) shows that the reaction can go according to the scheme:

$$nR'R''CO + Si(OR)_4 \overset{H^+}{\rightleftarrows} nR'R''C(OR)_2 + \frac{1}{m}[(RO)_{4-2n}SiO_n]_m \tag{3}$$
$$n = 0.5-2, \text{ a } m \geqslant 2.$$
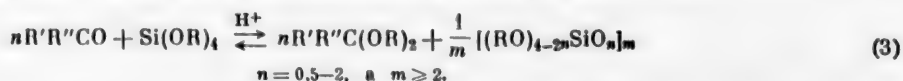
This scheme is analogous in form to the previously discovered reaction [14, 15] in which polydialkylsiloxanes are split by tetraalkoxysilanes.

$$\frac{n}{m}(R'R''SiO)_m + Si(OR)_4 \overset{RO^-}{\rightleftharpoons} nR'R''Si(OR)_2 + \frac{1}{m}[(RO)_{4-2n}SiO_n]_m \tag{4}$$
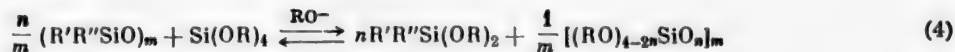
The possibility of accomplishing the acetalization of ketones** by means of tetraalkoxysilanes in the absence of alcohols is of undoubted practical interest, since it permits limitation of the original reactants to only two (tetraalkoxysilane and ketone), exlcuding from their number the corresponding alcohol. Moreover, the presence in the reaction mixture of a more or less significant quantity of alcohol makes it difficult to purify the acetals obtained (especially those with low boiling points) by any method, and leads to a considerable loss of the end product.

Numerous experiments on the reaction of tetraethoxysilane with acetone (in equimolecular ratio) in the presence of HCl, H_2SO_4, $NaHSO_4$, $C_6H_5SO_2OH$, H_3BO_3, BF_3, $ZnCl_2$ and others shows that the acetalization reaction does,

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*For the preceding report, see [1].

** The reaction of aldehydes with tetraalkoxysilanes in the presence of alcohols or without them is of only limited interest for the synth... is of acetals (for the preparation of the acetals of unsaturated aldehydes, for example), since in the absence of ketones aldehydes are easily acetalized by single alcohols [3-5].

in fact, take place. Orthophosphoric acid was found to be the best catalyst, in the presence of which the yield of the diethylketal of acetone amounted to 40%. It should be mentioned that we made use of anhydrous crystalline (100%) H_3PO_4 in order to avoid the possibility of forming alcohol by the hydrolysis of tetraethoxysilane by water present in the acid.[*] Nevertheless, even in this case formation of a very small quantity of alcohol may occur as a result of reaction between the catalyst and tetraethoxysilane [16].

$$3Si(OR)_4 + 4H_3PO_4 \rightarrow 12ROH + 3SiO_2 \cdot 2P_2O_5 \qquad (5)$$
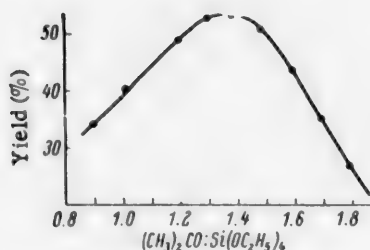
Dependence of the yield of the diethylketal of acetone on the molar ratio between $(CH_3)_2CO$ and $Si(OC_2H_5)_4$.

Further examination of the optimum ratio of reactants showed that the maximum yield of ketal (53-54% based on the original acetone) occurs at a 1.4-1.5 molar ration of $(CH_3)_2CO : Si(OC_2H_5)_4$ (see the chart). Thus the original quantity of tetraalkoxysilane may be reduced by approximately 50% in comparison with the amount used in the reaction (along with alcohol) by other authors [9, 12] who used acetone and $Si(OC_2H_5)_4$ at a molar ratio of 0.9-1.1. If the yield of the diethylketal of acetone is calculated on the basis of the more expensive tetraethoxysilane, the yield obtained (of the order of 80%) is entirely comparable with that obtained by other authors [9, 12] who used an unnecessary excess of $Si(OC_2H_5)_4$ and an additional quantity of anhydrous alcohol.

Experiments were carried out on the synthesis of the diacetalketals of the higher methylalkylketones CH_3COR ($R = C_2H_5$, n-C_3H_7, n-C_4H_9) of cyclopentanone and cyclohexanone, and also, for comparison, of butyraldehyde. In all cases the yields of the corresponding acetals amounted to 54%, calculating on the basis of the original carbonyl compounds (see the table). When mixtures of the components were heated for identical periods, the yield of the ketal of methylalkylketone decreased with increasing length of the hydrocarbon chain in the alkyl radical, which is entirely regular and which is also observed in the synthesis of ketals by other methods [17-19]. Therefore in the synthesis of the higher ketals, the reaction mixture was given more prolonged heating (14-20 hr instead of 10-14 hr in the case of acetone.) It was impossible to obtain the diethylketal of benzophenone by using this method, while the yield of the diethylketal of acetophenone was altogether negligible.

In order to study the influence of the nature of the organic radical in tetraalkoxysilanes on the course of their reactions with ketones, the reaction of the latter, not only with tetraethoxysilane, but also with tetramethoxy-, tetrabutoxy- and tetraphenoxysilanes was studied. It was found that tetrabutoxysilane, as might have been expected, forms acetals of ketones with more difficulty than tetraethoxysilane (the yield of the dibutylketal of acetone was 32%, while the dibutylketal of methylbutylketone was only 9%). Tetramethoxysilane, on the contrary, forms acetals more readily than $Si(OC_2H_5)_4$ (the yield of the dimethyl ketal of methylethylketone was 57%). Tetraphenoxysilane does not form ketals with ketones.

It was of interest to study the influence on the acetalizing reaction of the substitution of the ethoxy groups in tetraethoxysilane by methyl radicals. With this purpose in mind we examined the reaction of acetone and methylethylketone with methylethoxysilanes $(CH_3)_nSi(OC_2H_5)_{4-n}$ ($n = 1 - 3$). It was found that substitution of the ethoxy groups on the silicon atom by methyl groups considerably decreases the ability of ethoxysilanes to form acetals of ketones. Thus, for example, in the reaction of methylethylketone with dimethyldiethoxysilanes ($n = 2$), the yield of diethyl ketal was insignificantly small, while in the reaction of acetone with trimethylethoxysilanes practically no ketal formation was observed.

It should be noted that acetals in general, and ketals especially, are inclined to split off alcohol at elevated temperatures; this is greatly facilitated by acid catalysts [20]. Because of this the distillation of the acetals synthesized was carried out in the presence of sodium or its alcoholate. If this is not done the acetals are always contaminated by alcohol which has split off, and by the corresponding α, β-unsaturated ether.

Alcohol splits off most readily in the distillation of the ketals of cyclohexanone and its derivatives, beginning with 1-alkoxycyclohexenes (especially in the presence of acid catalysts [21-25]). This ability of the 1,1-dialkoxycyclohexanes offers an easy way to obtain 1-alkoxycyclohexenes, starting directly from cyclohexane and tetraalkoxy silanes.

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[*] For practical purposes this is not at all essential, and the use of H_3PO_4 in syrup form (85%) is even more expedient.

Compound	Formula	Boiling point ± 0.5° (pressure in mm)	d_4^{20}	n_D^{20}	Empirical formula	MR found	MR calc.	% C found	% C calc.	% H found	% H cal	Yield (%)
2,2-Dimethoxybutane	$CH_3(C_2H_5)C(OCH_3)_2$	108.9°(760)	0.8613	1.3930	$C_6H_{14}O_2$	32.75	33.19	60.98	60.95, 60.98	11.94	12.00, 11.88	57.0
2,2-Diethyoxypropane	$(CH_3)_2C(OC_2H_5)_2$	114.9 (760)	0.8294	1.3889	$C_7H_{16}O_2$	37.69	37.81	63.60	63.60, 63.82	12.20	12.27, 12.34	53.4
2,2-Diethoxybutane	$CH_3(C_2H_5)C(OC_2H_5)_2$	138.5 (760)	0.8412	1.3992	$C_8H_{18}O_2$	42.07	42.43	65.71	65.73, 66.01	12.41	12.45, 12.52	54.0
2,2-Diethoxypentane	$CH_3(C_3H_7)C(OC_2H_5)_2$	48.5 (12)	0.8418	1.4045	$C_9H_{20}O_2$	46.61	47.05	67.45	67.54, 67.19	12.58	12.34, 12.27	49.8
2,2-Diethoxyhexane	$CH_3(C_4H_9)C(OC_2H_5)_2$	71 (17)	0.8448	1.4095	$C_{10}H_{22}O_2$	51.06	51.67	68.92	68.30	12.72	12.45	53.0
1,1-Diethoxycyclopentane	(ring with OC_2H_5, OC_2H_5)	75 (29)	0.9089	1.4261	$C_9H_{18}O_2$	44.62	44.85	68.31	68.05	11.47	11.42	30.0
1,1-Diethoxycyclohexane	(ring with OC_2H_5, OC_2H_5)	85.3 (22)	0.9166	1.4369	$C_{10}H_{20}O_2$	49.23	49.47	69.72	69.88	11.70	11.86	43.0
1,1-Diethoxybutane	$C_3H_7CH(OC_2H_5)_2$	146.5 (760)	0.8285	1.3962	$C_8H_{18}O_2$	42.43	42.43	65.71	65.89, 65.82	12.41	12.25, 12.31	33.7
2,2-Dibutoxypropane	$(CH_3)_2C(OC_4H_9)_2$	85 (14)	0.8347	1.4127	$C_{11}H_{24}O_2$	56.22	56.28	70.16	70.25	12.85	12.62	32.0
2,2-Dibutoxyhexane	$CH_3(C_4H_9)C(OC_4H_9)_2$	115 (12)	—	1.4253	$C_{14}H_{30}O_2$	—	—	72.98	73.09, 72.90	13.13	13.26, 13.19	8.7
1-Methoxycyclohexene	(ring with OCH_3)	52 (32) 145.0 (760)	0.9224	1.4613	$C_7H_{12}O$	33.39	33.50	74.95	75.07, 75.34	10.78	10.93, 11.05	70.9
1-Ethoxycyclohexene	(ring with OC_2H_5)	63.5 (24)	0.9150	1.4589	$C_8H_{14}O$	37.70	38.12	76.14	75.67, 75.55	11.18	11.13, 11.21	63.2
1-Propoxycyclohexene	(ring with OC_3H_7-н.)	67 (9)	0.8901	1.4580	$C_9H_{16}O$	42.99	42.74	77.09	76.63, 76.72	11.50	11.49, 11.54	60.0
1-Butoxycyclohexene	(ring with OC_4H_9-н.)	83 (10)	0.8912	1.4602	$C_{10}H_{18}O$	47.42	47.36	77.87	77.95, 78.11	11.76	11.82, 11.86	60.2
1-Isoamoxycyclohexene	(ring with OC_5H_{11}-изо)	90 (9)	0.885	1.4599	$C_{11}H_{20}O$	52.0	51.94	78.51	78.25, 78.45	11.98	11.93, 11.76	55.0

$$n \langle \bigcirc \rangle = O + Si(OR)_4 \xrightarrow{H^+} n \langle \bigcirc \rangle - OR + \frac{1}{m} |(RO)_{4-2n}SiO_n|_m + nROH \tag{6}$$
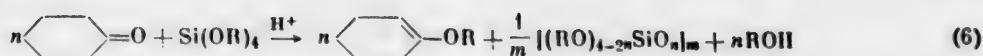
The synthesis is accomplished by the simple distillation of a mixture of cyclohexanone with the corresponding tetraalkyloxysilanes (in the presence of a catalytic quantity of H_3PO_4) after preliminary boiling for 8-14 hr. In this case nearly the theoretical quantity of alcohol is distilled off, followed by the reaction product containing alcohol, which is further purified by redistillation over sodium, preferably under reduced pressure (sometimes after treatment with 30% NaOH). This is the way in which the five 1-alkoxycyclohexenes shown in the table were obtained with yields of 55-70%. It should be noted that if distillation of the reaction mixture is carried out immediately, without preliminary heating, only an insignificant amount of the alcohol is separated and the reaction stops. This shows that the presence of a certain quantity of alcohol in the reaction mixture plays an essential role in the process of acetal formation.

The mechanism of the reaction of alkoxysilanes with carbonyl compounds may be presented in the following manner. Inasmuch as the reaction is catalyzed by acids, its first stage is the interaction of a proton of the acid with an oxygen of the carbonyl group (apparently through a hydrogen bond in the first place), with the formation of an electrophilic mesomeric carboxonium cation (A): $> C = O + H^+ \rightleftharpoons > C = O^+ - H \leftrightarrow C^+ - O - H$, which is more active than the original carbonyl compound. The electrophilic attack of this cation (as the carbonium ion) on the neutral molecule of alkoxysilane (8a) or more probably of alcohol (8b), owing to coordination with the unshared electron pair of the oxygen of the alkoxy group, leads to the formation of a carboxonium cation (B), the reaction of which with alcohols results in the formation of

$$\begin{array}{c} HO \quad\quad Si \lessgtr \quad\quad\quad Si \lessgtr \\ | \quad\quad\quad | \quad\quad\quad\quad | \\ >\overset{+}{C} + \; :O - R \rightleftharpoons \; C - \underset{+}{O} - R \rightleftharpoons >\overset{+}{C} \overset{\frown}{O} - R + HOSi \lessgtr \quad (8a) \\ (B) \end{array}$$

$$\begin{array}{c} HO \quad\quad H \quad\quad\quad H \\ | \quad\quad\quad | \quad\quad\quad | \\ >\overset{+}{C} + \; :O - R \rightleftharpoons >C - \underset{+}{O} - R \rightleftharpoons >\overset{+}{C} \overset{\frown}{O} - R + H_2O \quad (8b) \\ (B) \end{array}$$
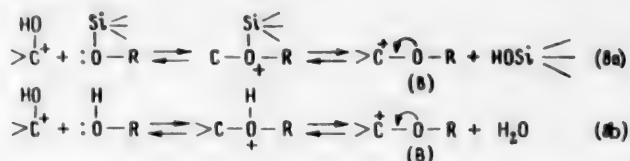
acetals and the freeing of a proton which serves as a catalyst.

$$\begin{array}{c} OR \quad H \quad\quad RO \\ | \quad\quad | \quad\quad\quad | \\ >\overset{+}{C} + O - R \rightleftharpoons >C - \underset{+}{O} - R \rightleftharpoons >C(OR)_2 + H^+ \end{array} \tag{9}$$
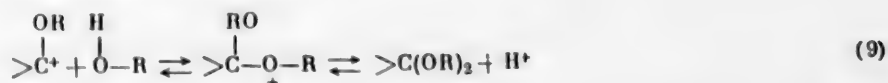
The following reactions undoubtedly result in the formation of alcohol, which is an intermediate product:

$$\rangle Si - O - R + H_2O \rightleftharpoons \rangle SiOH + ROH \tag{10}$$

$$\rangle SiOH + ROSi \langle \rightleftharpoons \rangle Si - O - Si \langle + ROH, \tag{11}$$
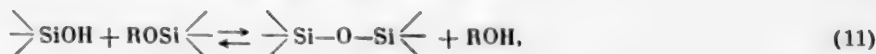
with water being formed not only as a result of reaction (8b) but also of (12):

$$\rangle SiOH + HOSi \langle \longrightarrow \rangle SiOSi \langle + H_2O \tag{12}$$
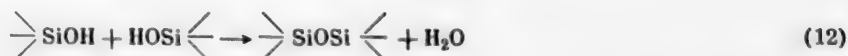
By comparing the yields of the diethylacetals of methylethylketone and of butyraldehyde, which is metameric with it, one may conclude that ketones form acetals more easily than aldehydes, which at first glance appears unexpected. This is entirely regular, however, since the accumulation at the carbonyl group of electron-repelling alkyl groups (+ I-effect) leads to an increase in the nucleophilic properties of the carbonyl oxygen in consequence of an increase in its negative charge and, consequently, facilitates the formation of cation (A).

$$\begin{array}{c} R \\ \rangle C = \overset{\frown}{O} \\ R \end{array}$$
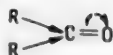
The introduction of a double bond in the α,β-position in the carbonyl group must lead to a similar effect:

$$CH_2 = \overset{\frown}{CH} \overset{\frown}{\cdot} CH = \overset{\frown}{O}$$

As a matter of fact, crotonaldehyde forms an acetal with tetraethoxysilane considerably more easily than the saturated aldehyde [12].

Thus, the opinion which is widely dispersed in the literature that aldehydes form acetals considerably more easily than ketones may only be explained by the fact that ketals hydrolyze much more rapidly than aldehydeacetals [26]. Because of this, the equilibrium of the reaction of the formation of acetals by means of alcohols, which proceeds with the separation of water, is considerably more easily displaced toward the right than in the case of the ketones.

EXPERIMENTAL

Initial reactants. Tetraethoxysilane— the commercial product (TU EU-64-54) was purified by distillation in a column over sodium and had b.p. 168.3° (760 mm), $n^{20}D$ 1.3830. The remaining tetraalkoxysilanes were described previously [27]. The initial ketones and the butyraldehyde (c.p.), after drying, were distilled through a column immediately before use. Their constants corresponded with the most reliable data in the literature. The crystalline orthophosphoric acid (a. p.) was the commercial product (GOST 6552-53).

Method of study. All syntheses of ketals were carried out in an apparatus with ground glass joints,consisting of a round bottomed flask with a thermometer and a bead reflux condenser supplied with a calcium chloride tube.

0.7-0.75 M of the carbonyl-containing compound, 0.5 M of tetraethoxysilane and 0.5-0.8 g of finely pulverized orthophosphoric acid were placed in the flask. The mixture was heated for from 12-18 hr, after which it was allowed to stand overnight at room temperature. Further treatment of the reaction mixture was carried out in two ways (A and B).

A. The mixture was mechanically agitated for one hour with 300 ml of a 30% aqueous solution of NaOH. An organic layer separated, was washed with water, dried over anhydrous potash, and fractionated at ordinary pressure or in vacuo.

B. The mixture was filtered and fractionated over 0.2-0.4 g of sodium at ordinary or at reduced pressure. The fraction corresponding to the acetal, boiling within 20-40° limits, was treated further according to method A.

In both cases the acetal, separated as a fraction boiling within limits of 5-10°, was repeatedly distilled in a column (the high boiling acetals were distilled in vacuo) preferably over sodium.•

For the synthesis of 1-alkoxycyclohexenes, a mixture of 0.7 M of cyclohexanone, 0.5 M of the corresponding tetraalkoxysilane (or of its mixture with 3 moles of a higher alcohol) and 1 g of H_3PO_4 was boiled for 10-14 hr, after which it was slowly distilled from the same flask (the reflux condenser was replaced by a 20 cm Vigreaux dephlegmator) until all the alcohol that had split off was removed. The remainder wasfractionated at ordinary or at reduced pressure. The 1-alkoxycyclohexenes obtained were purified from traces of cyclohexanone by treatment with sodium, first in the cold and then during distillation.

Descriptions of three typical experiments are given below.

The diethylketal of acetone (2,2-diethoxypropane). 40.7 g of tetraethoxysilane and 0.8 g of orthophosphoric acid were boiled for 12 hr. During this time the boiling temperature increased from 72 to 79°. After filtration the mixture was fractionated over 0.2 g of sodium. This fraction, after washing with a 25% solution of NaOH,and water, and drying over sodium, was again distilled over sodium. The yield was 49.4 g (53.4%) of a pure substance with b.p. 114.9°.

The diethylketal of cyclohexanone (1,1-diethoxycyclohexane). 68.7 g of cyclohexanone, 104.2 g of tetraethoxysilane and 1 g of orthophosphoric acid were boiled for 19 hr. The mixture was shaken for one hour with 300 ml of a 25% solution of NaOH, washed with water, dried over potash, and twice distilled in vavuo over sodium. 51.9 g (43%) of ketal with b.p. 85.3° (22 mm) and $n^{20}D$ 1.4369 was obtained.

1-Methoxycyclohexene. A mixture of 68.7 g of cyclohexanone, 76.1 g of tetramethoxysilane and 1 g of H_3PO_4 was boiled for 12 hr.•• Then the gelatinous mixture was subjected to slow distillation. At 64-65° 20.5 g (91%) of

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•Microdeterminations of carbon and hydrogen were made by Yu. N. Platonov, towhom the authors express their thanks.
• •Without preliminary boiling of the reaction mixture, some 1-3 g of CH_3OH are driven off and the reaction stops. It was not possible to increase the yield of alcohol by increasing the original quantity of catalyst, nor by adding a new portion of it.

methyl alcohol passed over. After removal of the methyl alcohol from this broad fraction, it was treated with sodium to remove traces of cyclohexanene and redistilled over sodium in vacuo. The yield was 55.7 g (71%). B.p. 52° (32 mm), n^{20}D 1.4613.

SUMMARY

The reaction of tetraalkoxysilanes with aliphatic and alicyclic ketones was studied. It was shown that this reaction, catalyzed by anhydrous orthophosphoric acid, proceeds in the absence of alcohols, and leads to the formation of the corresponding ketals with yields up to 57%. By this means eight ketals and also the acetal of butyraldehyde were synthesized and characterized. A mechanism for the reaction was proposed. It was found that the reaction of tetraalkoxysilanes with cyclohexane offers a new, simple and convenient method for the synthesis of 1-alkoxycyclo-hexenes. Five compounds of this type were synthesized in this way.

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STUDIES OF AROMATIC COMPOUNDS
CONTAINING A LONG SIDE CHAIN

VI. PREPARATION OF p-SEC-ALKYLANILINES

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It is known that p-sec-alkylanilines may be prepared by the C-alkylation of olefins or alcohols in the presence of zinc chloride [1], or by the nitration of the corresponding alkylbenzenes with subsequent reduction of the nitro group [2]. However it is not possible to obtain individual compounds in any considerable yield by these methods, since a mixture of products is obtained which is difficult to separate.

We proposed preparing p-sec-alkylanilines with a strictly determined location of the alkyl group by the ammonolysis of the corresponding p-sec-alkylchlorobenzenes, obtained from alkyl-(4-chlorophenyl)-ketones and alkyl-magnesium bromides as follows:
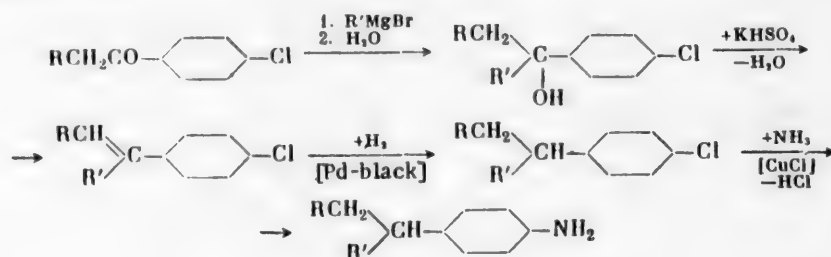
Starting with p-chloroaceto-, -propio-, butyro-, -valero-, -isovalero- and -caprophenone and alkylmagnesium bromides with R from C_2H_5 to C_9H_{19}, we obtained p-sec-amyl, p-sec-octyl - and p-sec-undecylanilines by this method; also methylpropyl-, methylhexyl-, ethylamyl-, propylbutyl-, propylisobutyl-, methylnonyl-, ethyloctyl-, propylheptyl, butylhexyl and diamyl-(4-aminophenyl)-methanes.

EXPERIMENTAL

Dialkyl-(4-chlorophenyl)-carbinols (Table 1). Into a three necked flask, supplied with a mixer, a reflux condenser and a dropping funnel with a calcium chloride tube, 1 g-atom of magnesium shavings and 150 ml of absolute ether were placed. To this mixture, while boiling moderately, was added dropwise a solution of 1 M alkyl bromide in 150 ml of absolute ether. The reaction mixture was gently warmed on the water bath until an energetic reaction began, and then stirred until solution of the magnesium was complete. Then during the course of an hour was added a 0.5 g-mole solution of alkyl-(4-chlorophenyl)-ketone in 100 ml of absolute ether. The mixture was stirred for one hour at room temperature and for five hours while boiling. After standing for 12 hr at room temperature the reaction mixture was decomposed in ice water. The ether layer was poured off, and the residue washed with ether and then dissolved in dilute hydrochloric acid. The solution was extracted again. After drying the ether extract over sodium sulfate and evaporation of the solvent, the carbinol was distilled in vacuo.

Dialkyl-(4-chlorophenyl)-methanes (p-sec-alkylchlorobenzenes). 0.1 g-mole of carbinol was added dropwise, in the course of one to two hours and at 40 mm, to 0.2 g-mole of potassium bisulfate which had been fused, pulverized and heated to 180° When the addition was completed, the mixture was held for one hour under these conditions,

TABLE 1. Dialkyl-(4-chlorophenyl)-carbinols
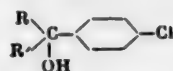
No.	R	R'	Yield (in %)	B.p. (pressure in mm)	n_D	Cl found (%)[*]
1	CH_3	C_3H_7	78.3	112—113° (3)		15.11, 15.31
2	CH_3	C_6H_{13}	67.8	130 (3.5)	1.5260 (18°)	14.87, 14.73
3	C_2H_5	C_5H_{11}	60.2	109—110 (3)	1.5244 (18)	15.22, 15.21
4	C_3H_7	C_4H_9	74.2	137—140 (7)	1.5238 (18)	16.08, 16.25
5	C_3H_7	iso -C_4H_9	52.6	108—110 (3)	1.5239 (18)	12.27, 12.10
6	CH_3	C_9H_{19}	69.3	155.5—156 (2)	1.5044 (21)	12.50, 12.40
7	C_2H_5	C_8H_{17}	70.8	150—151 (1.5)	1.5080 (20)	12.40, 12.70
8	C_3H_7	C_7H_{15}	80—85	165—166 (2.5)	1.5054 (20)	12.92, 13.00
9	C_4H_9	C_6H_{13}	69—77	165.5—166.5 (3)	1.5069 (20)	12.90, 13.01
10	C_5H_{11}	C_5H_{11}	66—73	160—162 (3)		

[*] Calculated %: Cl for $C_8H_{16}(OH)C_6H_4Cl$ is 14.75 and for $C_{11}H_{22}(OH)C_6H_4Cl$ it is 12.54. Some lack of coordination of the analytical data with the calculated values for chlorine may be explained by the partial dehydration of the carbinol during distillation.

TABLE 2. Dehydration of dialkyl-(4-chlorophenyl)-carbinols
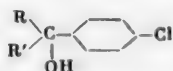
No.	R	R'	Yield (in %)	B.p. (pressure in mm)	n_D	Bromine number found[*]
1	CH_3	C_3H_7	78.3	74—75° (2)		87.37, 87.30
2	CH_3	C_6H_{13}	60.5	134 (5)	1.5290 (18°)	74.83, 74.61
3	C_2H_5	C_5H_{11}	91	118—120 (3)	1.5259 (18)	72.92, 73.29
4	C_3H_7	C_4H_9	94.3	115—117 (5)	1.5322 (18)	70.52, 70.47
5	C_3H_7	iso-C_4H_9	61.5	101—105 (3.5)	1.5311 (18)	74.92, 75.37
6	CH_3	C_9H_{19}	89—91	157.5—160 (3)	1.5150 (21)	
7	C_2H_5	C_8H_{17}	92—95	140.5—142 (2)	1.5150 (21)	
8	C_3H_7	C_7H_{15}	92—94	150.5—152 (3)		
9	C_4H_9	C_6H_{13}	92—97	149—152 (3)	1.5140 (20)	
10	C_5H_{11}	C_5H_{11}	93	150—152 (3)	1.5136 (21)	

[*] The bromine number calculated for $C_5H_9C_6H_4Cl$ is 88.5 and for $C_8H_{15}C_6H_4Cl$ it is 72.

and then the unsaturated compound was distilled at 2-5 mm and subsequently redistilled in order to purify it. Unsaturated compounds with a fatty residue, containing C_5^- and C_8^- atoms were analyzed by determining the bromine number (Table 2).

Hydrogenation of the unsaturated compound was carried out on palladium black (3-4% of the weight of the hydrocarbon) at atmospheric pressure and 40°. This was done by dissolving 0.03 g-moles of it in 50 ml of alcohol, placing the solution with the catalyst in a pear-shaped 250 ml flask and agitating the mixture in a current of hydrogen for two to four hours. On completion of the hydrogenation, the palladium black was filtered off and the solution added to an equal quantity of water. The fatty layer of hydrocarbon was separated, dried over calcium chloride and distilled in vacuo. The p-sec-alkylchlorobenzenes obtained (Table 3) were subjected to ammonolysis without further purification.

Dialkyl-(4-aminophenyl)-methanes (p-sec-alkylanilines). 0.1 g-mole of copper chloride and 90 ml of a 35% solution of ammonia were heated for six hours in an autoclave at 250-260°. After extracting the amine from the

TABLE 3. Dialkyl-(4-chlorophenyl)-methanes

$$\underset{R'}{\overset{R}{>}}CH-\langle\ \rangle-Cl$$
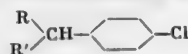
No.	R	R'	Yield (in %)	B.p. (pressure in mm)	n_D
1	CH_3	C_3H_7	88.5	74—75° (3)	1.5016 (18°)
2	CH_3	C_6H_{13}	85	130—134 (6)	1.5023 (18)
3	C_2H_5	C_5H_{11}	91.4	105—106 (2)	1.5077 (18)
4	C_3H_7	C_4H_9	93	115—118 (5)	1.5070 (18)
5	C_3H_7	iso-C_4H_9	96.5	105—107 (2)	
6	CH_3	C_9H_{19}	77	148—150 (3)	1.4913 (21)
7	C_2H_5	C_8H_{17}	90	146—148 (4)	1.4944 (21)
8	C_3H_7	C_7H_{15}	95	151—151.5 (4)	
9	C_4H_9	C_6H_{13}	90.5	152.5—153 (4)	1.4931 (20)
10	C_5H_{11}	C_5H_{11}	82	148—149.5 (3.5)	1.4919 (21)

TABLE 4. Dialkyl-(4-aminophenyl)-methanes

$$\underset{R'}{\overset{R}{>}}CH-\langle\ \rangle-NH_2$$
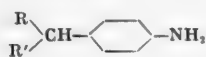
No.	R	R'	Yield (in %)	B.p. (pressure in mm)	n_D	Found, % N *	Benzoyl derivatives m.p.	found, % N **
1***	CH_3	C_3H_7	64	85—87° (2)		8.48, 8.53		
2	CH_3	C_6H_{13}	82	123—124 (2)	1.5120 (18°)	7.07, 7.04	106—106.5°	4.56, 4.56
3	C_2H_5	C_5H_{11}	82.5	130—32 (6)	1.5090 (18)	6.42, 6.34	109—109.5	4.70, 4.82
4	C_3H_7	C_4H_9	87.5	111—12 (1)	1.5139 (18)	6.77, 6.84	131—132	4.57, 4.71
5	C_3H_7	iso-C_4H_9	75.5	111—12 (3)	1.5242 (18)	6.65, 6.43	130—130.5	4.60, 4.75
6	CH_3	C_9H_{19}	66.5	158—60 (2)	1.5036 (21)	5.38, 5.20	109.5—110	4.00, 4.02
7	C_2H_5	C_8H_{17}	77.4	159 (2)	1.5033 (21)	5.87, 5.67	98—98.5	4.17, 3.99
8	C_3H_7	C_7H_{15}	82.4	149—150 (1)	1.5043 (21)	5.52, 5.60	91—91.5	4.31, 4.30
9	C_4H_9	C_6H_{13}	68.8	157—58 (3)	1.5059 (21)		90—91	4.30 4.26
10	C_5H_{11}	C_5H_{11}	79.8	142—43 (2)	1.5040 (21)	5.41, 5.55	97.5—98	3.80, 3.88

* Calculated %: N for p-sec-$C_5H_{11}C_6H_4NH_2$— 8.58; for p-sec-$C_8H_{17}C_6H_4NH_2$— 6.82; for p-sec-$C_{11}H_{23}C_6H_4NH_2$— 5.67.

* * Calculated %: N for p-isooctylaniline— 4.6; for undecylaniline— 3.98.

* * * Acetyl derivative, m.p. 104-104.3°. Found %: N 7.03, 6.96. Calculated %: N 6.84.

reaction mixture with ether, drying the ether solution over sodium sulfate and removal of the solvent, the amine was distilled in vacuo. The amines were purified by chromatography on aluminum oxide (Table 4).

SUMMARY

1. By reacting aliphatic-aromatic ketones with magnesiumhalogenalkyls, dialkyl-(4-chlorophenyl)-carbinols were synthesized. By the dehydration of these with subsequent hydrogenation at the double bond over palladium black, the following p-sec-alkylchlorobenzenes were obtained: methylpropyl-, methylhexyl-, ethylamyl-, propyl-butyl-, propylisobutyl-, methylnonyl-, ethyloctyl-, propylheptyl, butylhexyl-, diamyl-(4-chlorophenyl)-methanes.

2. The corresponding homologs of aniline were obtained in 75-85% yields by the ammonolysis of p-sec-alkyl-chlorobenzenes with a 35% solution of ammonia in the presence of copper chloride.

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THE HYDRATION OF A TRIPLE BOND
BY MEANS OF MERCURY IONS DEPOSITED
ON CATION EXCHANGES AND THE MECHANISM
OF THE REACTION

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On passing acetylene through catalytic solutions containing copper monochloride, ammonium chloride, sulfuric acid and an insignificant quantity of the sulfides of various metals, acetylene is hydrated to acetaldehyde with yields of up to 93% [1]. The hypothesis has been stated that the linking of various molecules with acetylene in a catalytic solution proceeds by a nucleophilic mechanism through the π-complex of acetylene [2].

Desiring to clarify the question of the reaction mechanism of combination with acetylene in the presence of ions of monovalent copper, we decided to carry out hydration by the aid of cation exchangers on which these ions were precipitated. A successful solution of this question would make it possible to show experimentally that in a given case the hydration catalyst is an ion of monovalent copper. However, it proved impossible to precipitate monovalent copper ions on cation exchangers. The hydration of acetylene and of acetylenic alcohols in the liquid phase was accomplished with the aid of mercury ions precipitated on various cation exchangers.

Data relating to the mechanism of the Kucherov reaction are few in number and contradictory. According to the hypothesis of a number of authors [3], mercury salts combine with acetylene during the hydration process and form an intermediate complex which, under the conditions of the reaction, later undergoes hydrolysis to acetaldehyde. Complex organomercury compounds, altogether different in composition and structure, were separated and approximately characterized [4]. In all probability these compounds are formed as byproducts and, apparently, have nothing to do with the reaction mechanism, inasmuch as the quantity of these insoluble and inactive organomercury compounds bears no constant ratio to the quantity of reaction products.

The high catalytic activity of divalent mercury ions on cation exchangers is experimental evidence of the fact that the hydration catalyst of the triple bond is the ion of divalent mercury. Precisely for this reason all salts of divalent mercury catalyze this reaction. Cationoids, introduced in the H^+-form, either by themselves or in water or in solutions of sulfuric acid of various concentrations, without the addition or after the addition of trivalent iron sulfate or of metallic mercury, are not hydration catalysts. A cation exchange catalyst is analogous to Kucherov's catalyst and gradually loses its activity in consequence of the reduction of the mercury ion to the metal. The addition of sulfuric acid and an increase in its concentration increase the yield of the reaction product. Introduction of trivalent iron sulfate increases the time that the catalyst is effective. Apparently the role of sulfuric acid as a hydrating agent is due not only to the fact that its anion, on combining with acetylene, forms vinylsulfate, but also to the fact that mercury sulfate is easily soluble in a solution of sulfuric acid, in consequence of which a certain concentration of divalent mercury ions, essential for hydration, is established in the catalytic solution. This reasoning is confirmed by the fact that mercury sulfate in aqueous solution is a poor catalyst for this reaction (see the table), while mercury ions (in a somewhat smaller quantity), precipitated on various cationoids, are good catalysts.

The results of our research, and also an analysis of the data in the literature, give foundation for the belief that the catalytic combination of various molecules with acetylene takes place because of the displacement of the π-electron pair of acetylene to an ion of the complex-former. This leads to a reduction in the electron density at the carbon atoms of acetylene, as a result of which they gain a partially positive charge. This polarization facilitates the

Composition of the catalytic solution							Quantity of C_2H_2 passed through (in liters)	Time (in hr)	Quantity of aldehyde (in g)	Conversion (%)
sulfocarbon (in g)	sulfocarbon Hg^{++} (in g)	H_2O (in ml)	H_2SO_4 (in g)	$Fe_2(SO_4)_3$ (in g)	Hg (in g)	KU-2 (in g)				
—	—	45	5	—	—	—	20		Traces	—
—	—	45	5	—	—	3	20		same	—
20	—	45	5	—	—	—	15	3	• •	—
20	—	45	5	3	—	—	20	3	• •	—
20	—	45	5	3	—	3	6	1	1.33	11
—	—	45	5	3	—	3	10.8	1	2.59	12
—	—	50	—	—	0.5	—	9.2	1	0.61	3.3
—	—	45	5	—	0.75	—	10	1	3.65	18.2
—	—	45	5	—	0.75	—	5.1	1	2.41	23.6
—	—	45	5	1.5	0.75	—	5.2	1	3.11	30
—	10	50	—	—	—	—	10.8	1	1.41	6.5
—	10	45	1 drop	—	—	—	10.5	1	2.80	13.3
—	10	45	2	—	—	—	10.5	1	2.80	13.3
—	10	45	5	—	—	—	8.7	1	3.12	18
—	10	45	12	—	—	—	10.1	1	3.88	19.2
—	10	45	12	—	—	—	9.1	1	3.85	21.1

nucleophilic attack of the combining molecule. The reaction mechanism of the hydration of acetylene may be considered in the following form:

The π-complex of acetylene with two molecules of water or with a molecule of water and one of sulfuric acid (in the case where hydration proceeds in the presence of sulfuric acid) forms an intermediate six-membered transfer ring, which facilitates the course of the reaction.
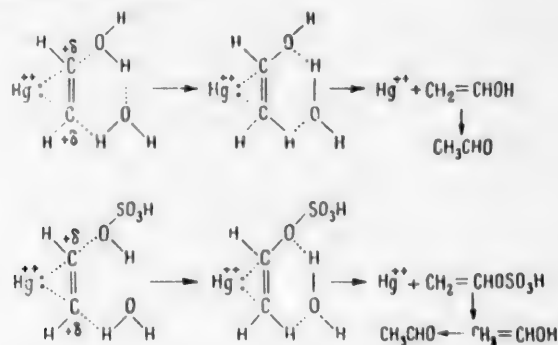
In the case of a copper catalyst the reaction mechanism is analogous.

EXPERIMENTAL

Cationite (KU-2 or sulfo-carbon) was first washed with water and then left in water for one day for maximum swelling. After pouring off the water it was treated with a 5-10% solution of sulfuric acid (for the purpose of shifting to the H^+-form) and then again carefully washed with water. The cationite, when ready for precipitation, was placed in a column and sprinkled several times with a 0.02-0.2 M $HgSO_4$ in sulfuric acid solution, after which it was carefully washed with distilled water until the SO_4^{--} ions were completely removed (test with a barium ion). The cationite treated in this manner is an active hydration catalyst for acetylenes.

The hydration of acetylene to acetaldehyde, according to Kucherov, was carried out in a reactor with a filter (which guaranteed good contact between the acetylene and the catalytic solution), placed in a thermostat at 85°. Acetylene from a cylinder, after purification through a meter, was allowed to enter the reactor. The gaseous mixture given off was absorbed by a neutralized 1% solution of hydroxylamine. The acetylene which did not react was allowed to escape into the atmosphere. The quantity of aldehyde formed was determined by the oxime method. Some of the experiments are shown in the table.

The hydration of dimethylethinylcarbinol. 40 ml of water and 10 g of catalyst (cationite KY-2 with precipitated mercury ions) were placed in a three-necked flask supplied with a reflux condenser, mechanical stirrer and a thermometer, and while the mixture was heated on a boiling water bath, 10 g of carbinol were added drop by drop. Heating of the reaction mixture was continued for four hours. The aqueous layer was extracted with ether. The ether extract was dried over magnesium sulfate. 7.2 g (60%) of 3-methylbutanol-3-one-2, with a b.p. of 133° and $n^{18}D$ 1.4175 were obtained.

Semicarbazone: m.p. 165-166° [5].

Hydration of methylethylethinylcarbinol. In similar manner 7.8 g (66%) of 3-methylpentanol-3-one-2, b.p. 41-43° (12 mm), $n^{20}D$ 1.4218, were obtained from 10 g of carbinol, 40 ml of water in the presence of 6 g of catalyst (sulfo- carbon with precipitated mercury ions).

Semicarbazone: m.p. 149-150° (from water) [6].

Hydration of ethinylcyclohexanol-1. 9.4 g (82%) of 1-acetylcyclohexanol-1: b.p. 84-85° (9 mm), $n^{16.5}D$ 1.4695 were obtained from 10 g of carbinol in 30 ml of water in the presence of 1 g of cationite KU-2 with precipitated mercury ions.

2,4-Dinitrophenylhydrazone: m.p. 143-145° (from alcohol) [7].

SUMMARY

1. The hydration of acetylene and acetylenic alcohols in aqueous solution with the aid of cationites of divalent mercury ions precipitated on them was accomplished.

2. It was determined that the catalyst is analogous to Kucherov's catalyst, and that it loses its activity with the passage of time. The divalent mercury ion is a hydration catalyst for the triple bond.

3. A mechanism for the hydration of a triple bond by mercury ions on cationite was proposed.

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THE SYNTHESIS OF α,ω-DI(2,4-DIHYDROXYBENZOYL)-ALKANES AND ARALKANES FROM DINITRILES AND RESORCINOL

N. A. Rybakova and E. N. Zil'berman

In the literature it is customarily assumed [1] that dinitriles with phenols of the type of resorcinol react, according to Hoesch, less smoothly than mononitriles, and that therefore it is difficult to prepare polyhydroxyarylketones in this way. One usually obtains α,ω-di-(2,4-dihydroxybenzoyl)-alkanes, ketonitriles or ketoacids (owing to the condensation of one nitrile group and the saponification of the other) with a small yield (up to 15%) [2, 3]. The synthesis of di-2,4-dihydroxybenzoyl derivatives of the alkanes and aralkanes by other means, for example the condensation of dibasic acids with resorcinol in the presence of zinc chloride [3] or sulfonic acids [4], does not always succeed. Moreover, according to the data of von Braun and his co-workers [3], the method is suitable for unbranched dibasic acids having no less than eight carbon atoms. When other dibasic acids are condensed with resorcinol, satisfactory yields of diketones are achieved only when a large excess (ten times) of resorcinol is used.

In the present study, diketones (I-V) were obtained by the condensation (in the presence of hydrogen chloride and zinc chloride) of the dinitriles of adipic, pimelic, azelaic, sebacic and n-xylylenediacetic acids with resorcinol. The preparation of diketones with high yields (up to 90%) succeeded because a modification of the Hoesch synthesis was used, which was worked out during the synthesis of 2,4-dihydroxybenzophenone [5], where it was shown that increased yield of the ketone may be achieved if phenol is admitted to the reaction only after the completion of the reaction of the nitrile with hydrogen chloride.

To synthesize the diketones, an excess of dry hydrogen chloride was passed into the solution of the dinitrile in ether in the presence of zinc chloride while the solution was kept cold; within 4-20 hr an excess of resorcinol was added, and after several days and nights the diketimine dichlorhydrate was hydrolyzed by boiling with water. When using the generally accepted method, i.e., by passing hydrogen chloride into the ether solution of nitrile and phenol, diketones were obtained in considerably smaller yields.

(I—V)

(I)   R = (CH₂)₄,   (IV) R = (CH₂)₈,
(II) R = (CH₂)₅,   (V)   R = CH₂—⟨ ⟩—CH₂.
(III) R = (CH₂)₇,
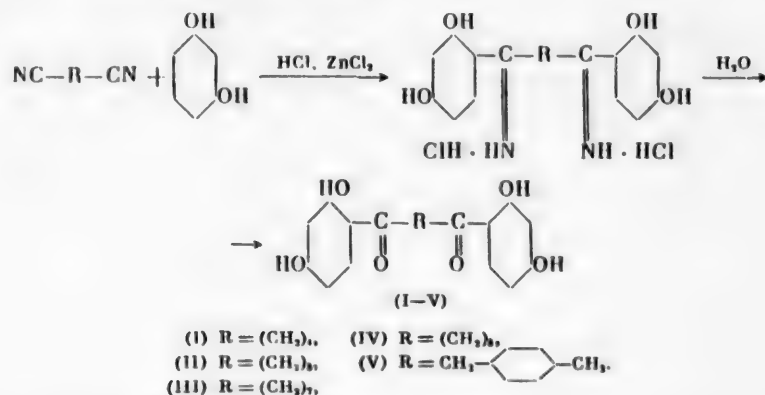
In the case of adiponitrile, despite an excess of resorcinol, along with a considerable yield (35%) of 2,2',4,4'-tetrahydroxyadipophenone (I), 1-(2,4-dihydroxybenzoyl)-4-cyanobutane (VI) was obtained. This is apparently explained by the fact that the first nitrile group in adiponitrile reacts considerably more easily than the second nitrile group [6]. Two products were also obtained from p-xylyldicyanide and resorcinol.

Ketones and Their Derivatives

| Ketone | Yield (%) | M.p. | | Analysis | | | | | | α,ε-Dinitrophenylhydrazones | | | |
| | | found | liter. data | found (%) | | empirical formula | calc. (%) | | decomp. temp. | empirical formula | nitrogen content, % | |
				C	H		C	H			found	calc.
(I)	40	285*	285 [2]	65.42	5.56	$C_{18}H_{18}O_6$	65.44	5.46	above 360°	$C_{30}H_{26}O_{12}N_8$	16.18	16.23
(II)	76	166	—	66.22	5.84	$C_{19}H_{20}O_6$	66.27	5.85	215	$C_{31}H_{29}O_{12}N_8$	15.54	15.90
(III)	79	114	141** [3]	67.08	6.63	$C_{21}H_{24}O_6$	67.72	6.50	275	$C_{33}H_{32}O_{12}N_8$	15.35	15.30
(IV)	90	172	168 [3]	68.72	6.66	$C_{22}H_{26}O_6$	68.37	6.78	263	$C_{34}H_{34}O_{12}N_8$	14.51	15.00
(V)	52	282*	—	69.57	4.92	$C_{22}H_{18}O_4$	69.82	4.79	above 360	$C_{34}H_{26}O_{12}N_8$	15.36	15.18
(VI)	35	156	158 [2]	—***		$C_{12}H_{13}O_3N$			253	$C_{18}H_{17}O_6N_5$	17.17	17.54

* Decomposed.

** Apparently the m.p. in [3] was erroneously overstated. The diketone (III) that we obtained according to the method in [3] had a m.p. of 114°; a mixed m.p. with (III), synthesized according to Hoesch, showed no depression.

*** Found %: N 6.16. Calculated %: N 6.39.

From the ketones we synthesized, corresponding 2,4-dinitrophenylhydrazones were obtained in almost theoretical yields; however in the majority of cases their melting (decomp.) points were not characteristic.

EXPERIMENTAL

2,2',4,4'-Tetrahydroxyadipophenone (I) and 1-(2,4-dihydroxybenzoyl)-4-cyanobutane (VI). A mixture of 10.8 g (0.1 mole) of the dinitrile of adipic acid, 8 g of freshly prepared, finely ground zinc chloride and 80 ml of dry ether, while being stirred and cooled to 0°, was saturated with dry hydrogen chloride for a period of three hours and then left to stand at 0°. The next day 33 g (0.3 moles) of resorcinol were added and the mixture was maintained at 0-10° for 48 hr. During this time the mixture separated into layers: the upper ether layer contained a small quantity of the original products which had not reacted; the lower layer was bright red in color and was a viscous, sticky substance. The layers were easily separated by decantation. On hydrolyzing the lower layer by boiling it with water, a substance was obtained in the form of hard small crystals which separated out from the still hot mother solution. By recrystallization from methanol, 16.3 g (I) of a slightly yellow substance were obtained, which was not easily soluble in the ordinary organic solvents. The aqueous mother solution was boiled down to half its volume and the precipitate obtained after cooling was filtered off. After recrystallization from dilute methanol, 8 g of ω-cyanobutyl-2,4-dihydroxyphenylketone (VI) were obtained. It was a pale yellow substance with crystals that looked like small sticks.

From 0.5 g of (I), 0.95 g (91%) of 2,4-dinitrophenyl hydrazone were obtained. From 0.5 g of (VI), 0.84 g (94%) of 2,4-dinitrophenyl-hydrazone were obtained. The constants and analyses of all the products prepared are shown in the table.

2,2',4,4'-Tetrahydroxypimelophenone (II), 2,2',4,4'-tetrahydroxyazelaphenone (III) and 2,2',4,4'-tetrahydroxy-sebacophenone (IV). Diketones (III) and (IV) were prepared from the corresponding nitriles (0.05 moles) and resorcinol (0.15 moles) as described above for (I). (II) and (III) were recrystallized from methanol and water (1 : 1); (IV) was recrystallized from methanol. Diketone (II) was obtained in the form of white needles; (III) and (IV) in the form of light yellow prisms and white needle-like crystals, respectively. (II) and (III) were readily soluble; (IV) was fairly insoluble in ordinary organic solvents. From the chilled mother liquor remaining after hydrolysis and the removal of (IV), 0.2 g of sebacic acid, m.p. 132° (from methanol); a mixed m.p. with a known sample of sebacic acid showed no depression. After evaporating the mother solution to half its volume, 1.5 g of material precipitated, the composition of which was not determined.

α,α'-Bis-(2,4-dihydroxybenzoyl)-p-xylylene (V). 7.5 g of a hard substance, which was worked up in hot aqueous methanol (1 : 1),were synthesized from 3.9 g of p-xylylenedicyanide and 8.25 g of resorcinol by a method analogous to that used for (I). The undissolved residue (5.0 g), after recrystallization from methanol, was pure (V) and gave light yellow rhombic crystals. From the aqueous methanol a precipitate was separated which according to its elementary composition was close to α'-2,4-dihydroxybenzoyl-α'-cyan-p-xylylene; however it was not identified.

SUMMARY

The possibility of using the Hoesch synthesis for preparing polyhydroxydiaryldiketones from dinitriles in high yields was demonstrated and the conditions worked out. Two previously unknown tetrahydroxydiaryldiketones were synthesized.

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SPECTRA AND HALOCHROMISM OF THIOPHENE ANALOGS
OF TRIPHENYL- AND DIPHENYLCARBINOL

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Aromatic carbinols on reacting with acids often form colored solutions [1]. This appearance of color is known in the literature as the phenomenon of halochromism [2]. In a number of studies it has been shown that the phenomeron of halochromism results from the ordinary process of acid-base interaction, which leads to the formation of a carbonium salt [3].

$$Ar_3COH + 2H_2SO_4 \rightleftarrows (Ar_3C)^+ + 2HSO_4^- + H_3O^+$$

Study of the absorption of neutral and acid solutions of aromatic carbinols showed that the spectra of carbonium ions are complex and enter into the visible range in consequence of the fact that the cations are colored [4]. The general appearance of the absorption curves, and also the number of bands of various carbonium ions is very strongly dependent on the quantity and character of the radicals.

There are no data in the literature on the absorption spectra of carbonium ions containing a thiophene ring. Meanwhile they are of definite interest for studying the problem of the coloring of organic compounds. Therefore a systematic investigation of the absorption spectra of neutral and acid solutions of a series of thiophene analogs of triphenyl- and diphenylcarbinol was undertaken.

The absorption curves of neutral solutions of trienyldiphenyl-, dithienyl- phenyl-, trithienyl-,[*] thienylphenyl- and dithienylcarbinols are located in the medium and short wave regions of the ultraviolet and have one high-intensity band of the thiophene type in the 2300-2400 A region (Fig. 1).

The absorption curves of sulfuric acid solutions of triphenylcarbinol and all of its thiophene analogs, in comparison with neutral solutions, are located well within the visible spectrum and have several absorption bands (Fig. 2). All these curves are so typical that by the appearance and the position of the bands it is entirely possible to characterize the carbinols, distinguishing one from another by the number of thiophene rings. The absorption curves of sulfuric acid solutions of diphenylcarbinol and its thiophene analogs also move into the visible range of the spectrum and have a characteristic outline for each carbinol (Fig. 3). Figures 4-6 show the absorption curves of solutions of carbinols in sulfuric and phosphoric acids, mixed with acetic acid, in trichloroacetic acid, and also in an alcoholic solution of hydrogen chloride.

Comparison of the absorption curves of neutral solutions of all carbinols with the curves of acid solutions show that the thiophene analogs of triphenyl- and diphenylcarbinol form the corresponding carbonium salts with acids. Substitution of benzene rings for thiophenes in aromatic carbinols increases their basic properties and facilitates acid-base interaction. This is evident, for example, from the fact that diphenylcarbinol with an alcoholic solution of hydrogen chloride does not give coloration, while dithienylcarbinol does. An analogous picture is observed on dissolving triphenylcarbinol and dithienylphenylcarbinol in an alcoholic solution of hydrogen chloride.

Comparison of the absorption maxima in the visible region of sulfuric acid solutions of triphenylcarbinol with that of thienyldiphenylcarbinol, and of diphenylcarbinol with that of thienylphenylcarbinol shows (Fig. 1) that substitution of one phenyl for thienyl brings about a marked bathochromic effect which is equal to 350 A. The

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[*] Trithienylcarbinol is extremely unstable. Therefore a solution of trithienylperchlorate in dichloroethane decolorized with alcohol was used for the study. The perchlorate was also used for the preparation of acid solutions instead of the carbinol.

Fig. 1. In C_2H_5OH: 1) Thienyldiphenylcarbinol, 2) dithienylphenylcarbinol, 3) trithienylmethylperchlorate (in a mixture with dichloroethane), 4) thienylphenylcarbinol, 5) dithienylcarbinol.
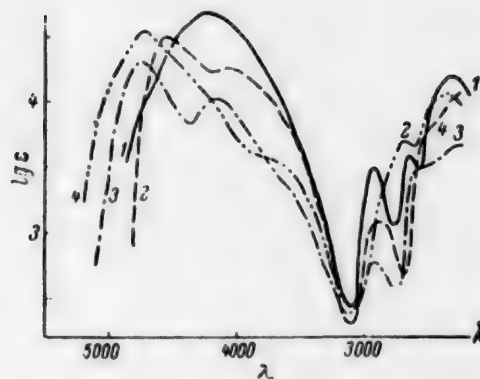
Fig. 2. In concentrated H_2SO_4: 1) Triphenylcarbinol, 2) thienyldiphenylcarbinol, 3) dithienylphenylcarbinol, 4) trithienylmethylperchlorate.
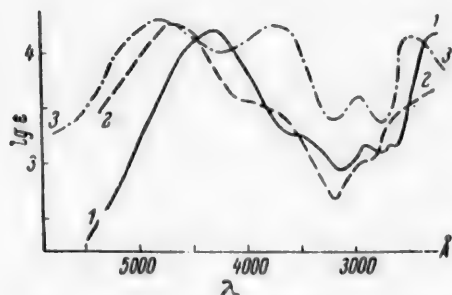
Fig. 3. In concentrated H_2SO_4: 1) Diphenylcarbinol, 2) thienylphenylcarbinol, 3) dithienylcarbinol.
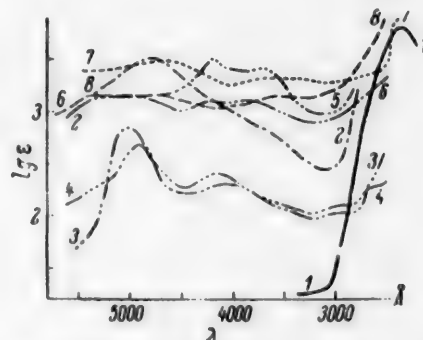
Fig. 4. Thienylphenylcarbinol: 1) in C_2H_5OH + + 5 N HCl, 2) in 90% CCl_3COOH, 3) in 44% H_3PO_4 in CH_3COOH, 4) in 30% H_2SO_4 in CH_3COOH. Dithienylcarbinol: 5) in 90% CCl_3COOH, 6) in 30% H_2SO_4 in CH_3COOH, 7) in 44% H_3PO_4 in CH_3COOH, 8) in C_2H_5OH + 5 N HCl.

introduction of a second diphenyl results in a somewhat smaller bathochromic displacement—of from 170-200 A. Bathochromic displacement of the long-wave band is also characteristic of acid solutions of other carbinols.

On introducing a thienyl group into a secondary carbinol a much greater hypsochromic effect is observed than from the introduction of a phenyl group. Thus, on going from dithienylcarbinol to dithienylphenylcarbinol it is equal to 120 A, while on going from triphenylcarbinol to trithienylcarbinol it is 150 A. A considerably greater intensity of the long wave absorption bands is apparently connected with the greater basicity of the first compounds.

Carbinols	C$_2$H$_5$OH		H$_2$SO$_4$	
	λ_{max}	ε	λ_{max}	ε
Triphenyl-	2600	630	4200	50200
Thienyldiphenyl-	2340	9440	4550	33200
Dithienylphenyl	2365	10500	4750	20500
Trithienyl-	—	—	4720	35500
Diphenyl	2580	468	4350	17000
Thienylphenyl-	2360	10770	4700	19500
Dithienyl-	2360	24270	4870	21400
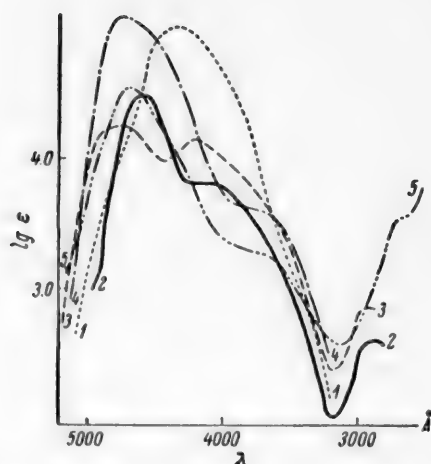
Fig. 5. In 90% CCl$_3$COOH: 1) triphenylcarbinol,
2) thienyldiphenylcarbinol, 3) dithienylphen-
ylcarbinol, 4) trithienylmethylperchlorate in
dichloroethane, 5) trithienylmethylperchlorate.
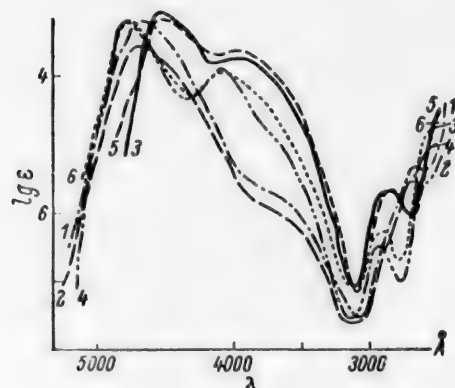
Fig. 6. Trithienylmethylperchlorate: 1) in 30%
H$_2$SO$_4$ in CH$_3$COOH, 2) in 44% H$_3$PO$_4$ in CH$_3$COOH.
Dithienylphenylcarbinol: 3) in 30% H$_2$SO$_4$ in
CH$_3$COOH, 4) in 44% H$_3$PO$_4$ in CH$_3$COOH.
Thienyldiphenylcarbinol: 5) in 30% H$_2$SO$_4$ in
CH$_3$COOH, 6) in 44% H$_3$PO$_4$ in CH$_3$COOH.

EXPERIMENTAL

Thiophene analogs of diphenyl- and triphenylcar-
binol were prepared by using the Grignard reaction and
purified by repeated recrystallization to constant melting point. Thienylphenylcarbinol was obtained from thiophen-
aldehyde and phenylmagnesium bromide (m.p. 57-58°); dithienylcarbinol from thiophenaldehyde and thienylmag-
nesium bromide (m.p. 57°); diphenylthienylcarbinol from benzophenone and magnesiumiodothiophene(m.p. 128°);
dithienylphenylcarbinol from the ethyl ester of benzoic acid and 2-thienylmagnesiumiodide (m.p. 90.5-91°); tri-
thienylmethylperchlorate from the ethyl ester of 2-thiophenylcarboxylic acid and 2-thienylmagnesiumiodide with
subsequent treatment with 70% perchloric acid.

The absorption spectra were measured on an SF-4 spectrophotometer.

SUMMARY

1. Comparative spectrophotometric studies of thiophene analogs of triphenyl and diphenylcarbinols in neutral
and acid solutions were made.

2. It was found that the thiophene analogs of aromatic carbinols, like triphenyl- and diphenylcarbinols,in acid
solutions have absorption spectra which are characteristic of various types of carbonium ions.

3. The bathochromic displacement of the long-wave bands, observed on substituting benzene rings for thio-
phenyl groups, gives evidence of the stronger nucleophilic influence of the 2-thienyl group in comparison with the
phenyl group.

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UNSATURATED HYDROCARBONS

XIII. THE DIRECTION AND LIMITS OF APPLICABILITY

OF THE DEHYDROCYCLIZATION REACTION

IN THE SYNTHESIS OF POLYPHENYLS

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Aromatization over aluminum-chromium catalysts of aryl-substituted compounds with an aliphatic chain containing four or five carbon atoms, results in the formation of naphthalenic hydrocarbons [1]. With lengthening of the aliphatic chain to six carbon atoms, a change in the direction of the reaction occurs and a series of biphenyl hydrocarbons is obtained [2]. On the dehydrocyclization of cyclohexenylisopropenylacetylene and of the dehydration products of 1-(1'-hydroxycyclohexyl)-3-phenylbutanol-3, β-methyl- [3] and β-phenylnaphthalene [4] respectively are formed.

The aromatization of aliphatic compounds with a cyclohexyl substituent and a sufficiently long carbon chain have not as yet been studied. Which of two possible directions the reaction takes (toward naphthalene or biphenyl) has been clarified in the present paper. The substance selected for study was 1-(1'-hydroxycyclohexyl)hexanol-3 (I), obtained by the hydrogenation of 1-(1'-hydroxycyclohexyl)hexene-1-ol-3 (II). The diol [II] was synthesized according to Iotsich in two ways— by the condensation of hexene-1-ol-3 with cyclohexane, and 1-ethynylcyclohexanol with butyraldehyde. The dehydrocyclization was carried out over $MgO/Cr_2O_3/Al_2O_3$ (2 : 18 : 80) as a catalyst. Biphenyl was separated from the reaction products; under optimum conditions (530°; 0.40 kg/ liter cat. hour) its yield was 33% of theoretical.
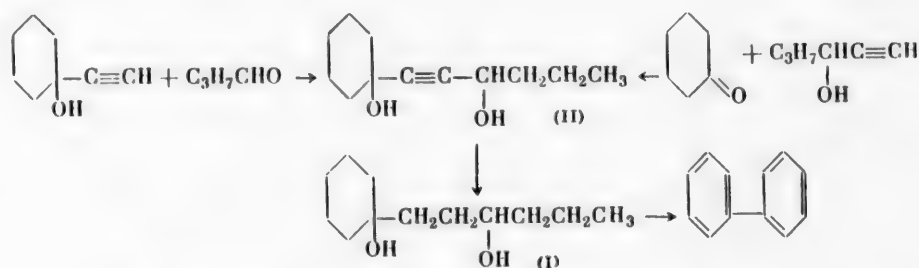
Efforts to detect alkylnaphthalenes in the corresponding fractions of the catalyzate, either by the use of ultraviolet absorption spectra or the formation of picrates, gave negative results. Thus the substitution of a phenyl radical by a cyclohexyl radical in the original compound does not change the general direction of dehydrocyclization. The complete similarity in the behavior of both compounds, however, may be attributed to preliminary dehydrogenation of the cyclohexyl substituent.

In view of the fact that the most interesting polynuclear hydrocarbons from polyphenyls are of the para series, we tried to show, by the example of n-quarterphenyl, the possibility in principle of using the described reaction for their synthesis. p-Quaterphenyl is obtained as follows:

$$\rightarrow \text{(biphenylyl)}-\underset{\underset{OH}{|}}{\overset{\overset{CH_3}{|}}{C}}-C\equiv C-\underset{\underset{OH}{|}}{\overset{\overset{CH_3}{|}}{C}}-\text{(phenyl)}\rightarrow \quad \text{(III)}$$

$$\rightarrow \text{(biphenylyl)}-\underset{\underset{OH}{|}}{\overset{\overset{CH_3}{|}}{C}}-CH_2CH_2-\underset{\underset{OH}{|}}{\overset{\overset{CH_3}{|}}{C}}-\text{(phenyl)}\rightarrow \quad \text{(IV)}$$

$$\rightarrow \text{(quaterphenyl)}$$
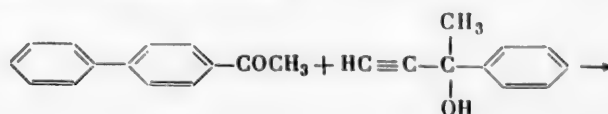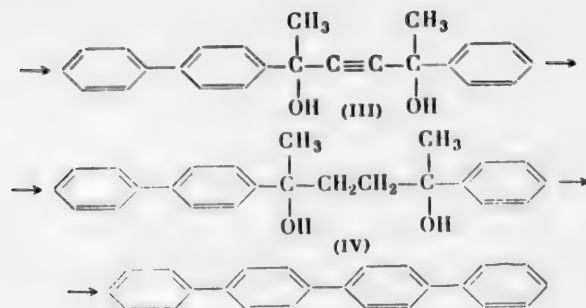
2-Phenyl-5-p-biphenylylhexene-3-diol-2,5 (III), prepared according to the Iotsich reaction, was found to be a mixture of isomers from which it was possible to separate a racemate with m.p. 145-145.5°. On hydrogenation it forms 2-phenyl-5-p-biphenylylhexanediol-2,5 (IV) with m.p. 95.5-96°. Another isomer (IV) with m.p. 136-136.5° may easily be separated by hydrogenating a mixture of isomers (III). The dehydrocyclization of glycol (IV) (both as individual isomers, as well as their mixtures) gives n-quaterphenyl with a yield of 16-18%. Consequently the method studied, in principle, permits the preparation of higher polyphenyls.

Ultraviolet absorption spectra were taken in order to characterize intermediate products (III, IV). These spectra (see figure) are hardly adequate for the identification of the compounds mentioned, since the presence of a biphenylyl residue in their molecules is the decisive factor in determining absorption. The glycols (III) and (IV), as well as the weakly absorbing diol (I) in the synthesis of biphenyl, give more clearly defined x-ray constants (Table 1).

Ultraviolet absorption spectra (in 95% alcohol). I) 2-Phenyl-5-p-biphenylylhexene-3-diol-2,5 (m.p. 145°); II) 2-phenyl-5-p-biphenylhexanediol-2,5 (m.p. 95.5°); III) 2-phenyl-5-p-biphenylylhexandiol-2,5 (m.p. 136°.

EXPERIMENTAL

1-Ethynylcyclohexanol, hexyne-1-ol-3 and 3-phenylbutyne-1-ol-3 were synthesized according to the Favorskii reaction by the condensation of the corresponding carbinols with acetylene under pressure, using the method described by one of us [5].

1-(1'-Hydroxycyclohexyl)hexyne-1-ol-3 (II). This was prepared according to Iotsich from 37.8 g of magnesium, 173 g of ethyl bromide, 93 g of 1-ethynylcyclohexanol and 42.5 g of butyraldehyde. Decomposition by means of water and 2-5% sulfuric acid was carried out during a period of 72 hr. The product was distilled in small portions in vacuo and in a current of nitrogen. The yield was 85.1 g (73.5%); b.p. 138-139 (2 mm), $n^{20}D$ 1.4962.

Found %: C 73.00; H 10.25. $C_{12}H_{20}O_2$. Calculated %: C 73.41; H 10.27.

It may be prepared from hexyne-1-ol-3 and cyclohexanone in an ether-benzene solution. Yield 84.3%.

The hydrogenation of 1-(1'-hydroxycyclohexyl)hexyne-1-ol-3 (II). 43 g of glycol (II) were hydrogenated in a methanol solution on a nickel catalyst at 18° and with an initial hydrogen pressure of 80 atm. After removing the solvent, the remainder was distilled in vacuo; apparently during this procedure part of the 1-(1'-hydroxycyclo-hexyl)hexanol-3 (I) dehydrated. The yield was 34 g (77.5%); b.p. 138-139° (2 mm); it crystallized on standing, m.p. 37-39°. It is easily soluble in the ordinary organic solvents.

Found %: C 71.89; H 12.16. $C_{12}H_{24}O_2$. Calculated %: C 71.95; H 12.08.

The dehydrocyclization of 1-(1'-hydroxycyclohexyl)-hexanol-3 (I). Aromatization was carried out in a circulating system previously described [2] over 25 ml of a catalyst consisting of $MgO/Cr_2O_3/Al_2O_3$ (2 : 18 : 80) at 530°. 170 ml of a 20% benzene solution of I were introduced into the reaction vessel during a period of three hours and

TABLE 1. X-ray Constants

I	d	I	d	I	d	I	d
			1-(1'-Hydroxycyclohexyl)hexanol-3				
7br	10.7	5	5.16	2	3.20	5	2.164
2	9.7	10 br	4.65	5	2.95	1	2.097
3	8.8	1 br	4.21	2	2.84	1	2.041
3	7.78	6	3.88	3	2.68	2	1.941
2	6.90	4	3.64	2	2.330	1	1.920
2	5.85	4	3.24	1	2.226	2	1.760
			2-Phenyl-5-p-biphenylylhexene-3-diol-2,5 (m.p.145-145.5°)				
3	9.3	2	3.99	1	2.57	2	1.940
6	8.2	3	3.89	2	2.52	2	1.873
6	8.0	2	3.80	1	2.465	2	1.838
1	6.99	3	3.60	1	2.424	1	1.800
5	6.50	7	3.29	1	2.385	2	1.703
6	6.02	1	3.80	4	2.317	2	1.641
3	5.27	1	3.13	1	2.257	1	1.556
5	4.99	3	3.00	1	2.190	1	1.374
3	4.70	4	2.93	3	2.182	1	1.358
9 br	4.54	1	2.77	5	2.103	1	1.301
10 br	4.20	1	2.62	3	2.025	3	1.223
			2-Phenyl-5-p-biphenylylhexanediol-2,5 (m.p. 95.5-96.5°)				
3	9.4	3 dif.	2.91	3	1.893	1	1.385
3	8.7	2	2.84	2	1.868	2	1.349
4	7.36	2	2.72	1	1.826	2	1.325
7	6.26	4 dif.	2.60	2	1.803	1	1.283
5	5.83	4	2.52	2	1.747	1	1.275
4	5.46	3	2.417	2	1.706	1	1.239
4	5.16	4	2.288	1	1.636	2	1.230
10 br	4.68	2	2.230	1	1.606	1	1.213
10 br	4.21	1	2.180	1	1.554	2 dif	1.202
9	4.01	4	2.128	1	1.539	2	1.192
2	3.91	5	2.067	1	1.513	2	1.188
4	3.68	2	1.997	2	1.494	2	1.177
10	3.36	2	1.935	2	1.462	1	1.172
5	3.10			2	1.405		
			2-Phenyl-5-p-biphenylhexanediol-2,5 (m.p. 136-136.5°)				
2	11.5	7	4.09	2	2.60	4	1.986
10	10.2	5	3.85	4	2.495	3	1.948
2	7.38	10	3.70	2	2.433	3	1.916
4	6.57	5	3.52	2	2.345	3 dif	1.847
2	6.15	2	3.34	3	2.291	3	1.839
2	5.81	8	3.17	5	2.200	5	1.713
10	5.28	4	3.05	2	2.148	1	1.709
3	4.87	5	2.88	5	2.103	1	1.679
3	4.29	4	2.63	4	2.051	2 br	1.570

TABLE 2. X-ray Constants of p-Quaterphenyl

I	d	$d_{calc.}$	I	d	$d_{calc.}$	I	d	$d_{calc.}$
2	9.2	9.6	2	3.26	3.25	3	1.909	1.910
2	8.8	8 9	9	3.17	3.17	1	1.881	1.880
1	6.02	6.00	3	2.96	2.955	1	1.866	1.870
2	5.76	5.78	1	2.78	2.78	3	1.817	1.821
1	5.39	5.40	2	2.63	2.65	3	1.691	1.689
3	5.05	5.03	2	2.59	2.59	1	1.598	1.600
2	4.92	4.94	1	2.396	2 41	3	1.583	1.579
10	4.60	4.63	5	2.363	2.360	2	1.287	1.290
8	4.37	4.36	2	2.306	2.302	3	1.275	1.275
2	4.20	4.25	3	2.178	2.180	2	1.224	1.223
1	3.99	3.99	3	2.089	2.083	4	1.197	1.197
9	3.85	3.84	4	2.032	2.030	1	1.174	1.173
5	3.48	3.48	2	1.964	1.970			

twenty two minutes. After each 50 min of work, the apparatus was blown out with nitrogen and the catalyst regenerated by passing air over it at 600-650° for two to three hours; then nitrogen was blown through again. The resulting solution was distilled from a Favorskii flask. The fraction which had a boiling point of 240-255° (725-730 mm) which was principally biphenyl, crystallized instantly. Yield 7.17 g. From the fractions boiling at 200-230° and from 230-240°, by chilling them to from −15 to −20° and by washing them with cold alcohol, a further 0.2 and 1.3 g, respectively of biphenyl were obtained. The over-all yield was 33.1%; m.p. 69-69.5° (from alcohol); mixture with a known sample showed no depression of the melting point. The filtrate, after separation of the biphenyl (fraction with b.p. 230-240°) did not show the absorption in the 280-325 m μ region which is characteristic of alkylnaphthalenes. None of the catalyzate fractions formed picrates with an alcoholic solution of picric acid.

2-Phenyl-5-p-biphenylylhexyne-3-diol-2,5 (III). To the Iotsich complex of 9.6 g of magnesium, 44.1 g of ethyl bromide and 25.5 g of 3-phenylbutyne-1-ol-3 in 350 ml of ether were added 29.4 g of phenylacetophenone in 500 ml of benzene, and the mixture stirred for ten days. It was then decomposed with water while cooling with ice. The precipitate was extracted with ether and benzene. After distilling off the solvent in vacuo from the product which was stabilized with hydroquinone, the material remaining was pulverized in 70-100 ml of warm petroleum ether (b.p. 80-90°). On cooling, the product crystallized. The yield of glycol was 44.9 g (87.7%); m.p. 119-127° (from petroleum ether). A test of a mixture with phenylacetophenone showed m.p. 93-98°.

Found %: C 84.21; H 6.64. $C_{24}H_{22}O_2$. Calculated %: C 84.17; H 6.48.

The mixture of isomers was washed four times with ether (some 80-100 ml for 10 g) and recrystallized from it twice. The isomer separated in this fashion had a m.p. of 145-145.5°.

Found %: C 83.97; H 6.46. $C_{24}H_{22}O_2$. Calculated %: C 84.17; H 6.48.

2-Phenyl-5-p-biphenylylhexanediol-2,5 (IV). 6.4 g of the glycol isomer (III) with m.p. 145-145.5° in a solution of methanol was hydrogenated over a nickel catalyst at room temperature and atmospheric pressure. 980 ml of hydrogen (calculated: 960 ml) were absorbed. The catalyst was filtered off and the methanol distilled. The residue was a colorless, glass-like mass. Yield 6.3 g (97.2%). The glycol was pulverized in hot petroleum ether, cooled, the solvent poured off, and the residue dissolved in ether; crystals of glycol (IV) soon formed; this isomer (IV) has m.p. 95.5-96.5° (from ether).

Found %: C 83.18; H 7.61. $C_{24}H_{26}O_2$. Calculated %: C 83.19; H 7.58.

From 32 g of the mixture of isomers (III), on hydrogenating in an autoclave (60 atm) a mixture of glycol isomers (IV) was obtained in practically a quantitative yield; the material had a glass-like appearance.

On working it up, as indicated above, 15 g of crystals were obtained, which consisted principally of the high melting isomer (IV); m.p. 136-136.5° (from ether).

Found %: C 82.92; H 7.79. $C_{24}H_{26}O_2$. Calculated %: C 83.19; H 7.58.

p-Quaterphenyl. The aromatization of glycol (IV) was carried out under the usual conditions over 25 ml of a catalyst consisting of MgO/ Cr_2O_3/ Al_2O_3 (2 : 18 : 80). The original product (IV) was fed into the catalytic tube as a 20% benzene solution. The solution was evaporated to dryness, the residue stirred with a small quantity of ether, filtered off and washed with ether. The ether was removed from the filtrate (from several experiments) and products boiling up to 150° at 5-7 mm were distilled off. The residue was washed with ether, filtered, and combined with the basic portions of p-quaterphenyl. After recrystallization from benzene (1 g in 1 liter), the latter had a m.p. of 317.7-318.7° [6]. The test yields (16-18%) were obtained at 550° and a feeding rate of (IV) of 0.48-0.77 kg/ liter cat. hour. The catalyst quickly loses its activity, which apparently, is connected with the difficulty of removing from its surface the extremely high melting point and high boiling point products of the reaction. An increase of the charge of (IV) from 5 to 7-8 g appreciably reduces the yield.

X-ray constants of the crystalline substance obtained. The exposure was made in unfiltered CrK-emission at 25 kv and 14 ma; the time of exposure was three hours. The roentgenograms were taken on asymmetrically placed film according to Wilson's modification [7] in RKD-57.3 powder cameras. The diameter of the samples was 0.4 mm. In view of the insignificant absorption of the x-rays in the material of the samples, correction for their thickness was not made. The relative intensities of the J lines were judged visually, while the interplanar distances- $\underline{d}$ are given in kX-units; "br" indicates a broad line; "dif" indicates a diffuse line.

The x-ray constants are shown in Table 1.

Table 2 shows the x-ray constants of p-quaterphenyl. Data on the values d_{calc} of the interplanar distances, which were calculated from the magnitude of the parameters of the quaterphenyl lattice [8], are shown for comparison.

SUMMARY

1. Biphenyl was produced by the dehydrocyclization of 1-(1'-hydroxycyclohexyl)hexanol-3 on a chromium-aluminum catalyst, by which it was shown for the first time that aliphatic compounds with a six carbon chain and a cyclohexyl substituent aromatize into a series of biphenyl hydrocarbons, but not into naphthalene.

2. Using p-quaterphenyl as an example, the possibility of synthesizing polyphenyls of high molecular weight by catalytic aromatization was demonstrated.

3. The x-ray constants of the crystalline compounds obtained were determined.

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HALOARYLATION OF UNSATURATED COMPOUNDS
WITH AROMATIC DIAZO COMPOUNDS

XII. CHLOROPHENYLATION OF BUTADIENE AND ISOPRENE

A. V. Dombrovskii and N. I. Ganushchak

It was shown previously that butadiene (I) [1], isoprene (II) [2], and some other conjugated dienes react with benzenediazonium chloride (BDC) in aqueous acetone in the presence of $CuCl_2$, undergoing so-called chlorophenylation with the addition of a phenyl radical and a chlorine atom in the 1,4-position to form 4-chloro-1-phenyl-2-butenes (chlorophenylbutenes).

$$CH_2=C(R)CH=CH_2 + C_6H_5N_2Cl \xrightarrow{-N_2} C_6H_5CH_2C(R)=CHCH_2Cl(R=H, CH_3)$$
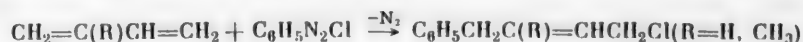
As a rule, the reaction is accompanied by a series of side processes to form $C_6H_5-CH=C(R)-CH=CH_2$, C_6H_6, C_6H_5Cl, azo resins, etc. Its course and direction is substantially affected by a series of factors and conditions.

In the present communication we give the results of studying the effect of the catalytic action of metal chlorides, the nature of the organic solvent, the medium pH, and the temperature on the yields of chlorophenylbutenes.

K. Meyer [3] and later A. P. Terent'ev [4] and B. A. Arbuzov [5] et al. showed that conjugated dienes, in particular, (I) and (II), react with aromatic diazo compounds to form unsaturated aliphatic-aromatic azo compounds of the type $Ar-N=N-CH=C(R)-CH=CH_2$. Elementary nitrogen is liberated from the diazo group in the presence of copper halides and chloroarylbutenes are formed [6].

As our experiments showed, practically no chlorophenylation of (I) or (II) occurs in the absence of $CuCl_2$ or when it is replaced by $ZnCl_2$, $HgCl_2$, $CdCl_2$, $SnCl_2$, $MnCl_2$, $NiCl_2$, $AlCl_3$, or $FeCl_3$. The specific activity of copper chloride is apparently explained by the peculiarities of the electronic structure of the copper atom. In this connection, it seemed interesting to establish the limits of the quantitative action of $CuCl_2$ introduced into the reaction. For this purpose, we carried out experiments on the chlorophenylation of (I) and (II) with various amounts of $CuCl_2$. The results obtained are given in Table 1, which shows that the highest yields of chlorophenylbutenes were obtained with 0.1-0.2 mole of $CuCl_2$ per mole of BDC in the reaction mixture. It should be noted that $CuCl_2$ was more efficient if the copper chloride solution was added preliminarily to the BDC solution and not mixed with the solution of the diene in the organic solvent.

It has been reported in the literature [7] that styrene may be chloroarylated in the presence of both $CuCl_2$ and CuCl and in this connection the opinion was put forward that the reaction is not catalyzed by $CuCl_2$, but cuprous chloride, which is formed from $CuCl_2$ by reaction with acetone, which is usually used as the organic solvent.

$$CH_3COCH_3 + 2CuCl_2 \rightarrow CH_3COCH_2Cl + HCl + 2CuCl_2$$

We established that in the reaction of (I) and (II) with BDC in the presence of CuCl in a nitrogen atmosphere, the chlorophenylbutene yields were lower (30-40%). In addition, it was found that a considerable part of the CuCl (~65%) was converted to $CuCl_2$, which is evidently the reaction catalyst. The conversion of monovalent to divalent copper is undoubtedly explained by the oxidizing action of BDC, which is thus reduced to benzene.

$$C_6H_5N_2Cl + 2CuCl + H_2O \rightarrow C_6H_6 + N_2 + Cu(OH)Cl + CuCl_2$$

It is relevant to note here that according to literature data [8], the arylation of maleic acid with arenediazonium chlorides in the presence of $CuCl_2$ gives the best results simply in aqueous solution in the absence of acetone. In this case, the water can hardly have a reducing action on the cupric chloride.

TABLE 1. Relation of Chlorophenylbutene Yields to the Amount of Cupric Chloride

$C_4H_5N_2Cl$: $CuCl_2$ (in moles)	Reaction time (hr)	Yields (in %) CPB *	Yields (in %) CMPB *
1 : 1	1.5—2	64	53
1 : 0.5	2—3	62	54
1 : 0.2	3	65—70	62
1 : 0.1	3	50	65—70
1 : 0.05	3.5—4	46	60
1 : 0.03	4	—	45
1 : 0.01	4—5	35	32
1 : 0	10—15	5	6

* In this and the following tables, CPB = = $C_6H_5CH_2CH = CHCH_2Cl$, and CMPB = = $C_6H_5CH_2C(CH_3) = CHCH_2Cl$.

Chloroarylation is usually carried out in a mixture of water and an organic solvent. The latter is used as most unsaturated compounds are insoluble in water, while water soluble arenediazonium chlorides are sparingly soluble in organic solvents. In cases where both components are soluble in water, the organic solvent is not required [8, 9]. If the organic solvent is necessary, its nature has a definite effect on the course of the reaction. We tested a series of solvents from different classes of organic compounds in the chlorophenylation of (I) and (II) (Table 2). The ratio of water to solvent chosen was such that the mixture obtained dissolved the unsaturated compound quite readily. These ratios were normally close to 1 : 1. The data in Table 2 show that the highest yields of chlorophenylbutenes were obtained when the reaction was carried out in mixtures of water and acetone or water and acetonitrile. In addition to their complete miscibility with water, both these solvents have comparatively high dielectric constants and dipole moments (21.5 and 2.95 D, and 38.8 and 3.94 D, respectively). These physicochemical characteristics of acetone and acetonitrile should not substantially impede the ionic reactions which apparently occur between the reagents in the initial phase of chlorophenylation. Though alcohols

TABLE 2. Effect of Organic Solvent on Chlorophenylation of Dienes (I) and (II)

Solvent	Temperature	Yields (%) CPB	Yields (%) CMPB
Acetone	0–5°	70	70
Acetonitrile	0–5	—	65
Methanol	3–4	30	—
Ethanol	5–10	48	40
n-Butanol	10–15	—	6
Dioxane	5–10	24	30
Pyridine	2–3	10	—
Acetone (in the absence of water)	0–25	No reaction	

have high values for the above constants, they themselves react chemically with BDC under the reaction conditions. Though they are miscible with water, such solvents as pyridine and dioxane reduce the catalytic action of $CuCl_2$ by binding it in chemical complexes. In addition, the dielectric constants of these compounds are very low. Water is a more important component than the organic solvent. As we showed, chlorophenylation does not occur in an anhydrous medium. Special experiments showed that butadiene in anhydrous acetone in the presence of $CuCl_2$ does not react with anhydrous (dry) BDC even with prolonged stirring and variation of the temperature from 0 to 25°. However, as soon as water was added to the mixture, the evolution of nitrogen began and the reaction proceeded in the normal way.

Table 3 gives the results of experiments on the chlorophenylation of (I) and (II) at various acidities of the medium. The best results were obtained with reactions in media with pH 4-6. To achieve this, we partly neutralized the BDC solution with sodium bicarbonate and to maintain the pH within the given range during the reaction, we added powdered CaO or MgO to bind the HCl liberated by side reactions. Chlorobenzene was formed in more acid

TABLE 3. Relation of Chlorophenylation of the Dienes (I) and (II) to Medium pH

Medium pH	Reaction temp.	Duration (hr)	Yields (%)	
			CPB	CMPB
1-2	14-16°	6-8	22	35
2-4	10-12	4	40	50
5 (in acetate buffer)	12-18	3	30	45
4-6	0-5	3	65-70	65-70
10-12	Tar formation		Tar formation	

media and tar was formed at higher pH values; the whole reaction mixture turned to a tarry mass in the pH range 10-12. It should be noted that in a buffer solution (ph ~5) produced by adding sodium acetate to the mixture, as is usually done in accordance with the directions of Meerwein et al. [10], the yields of chlorophenylbutenes were lower and there was considerable tar formation. It is evident that in this case the acetate radicals formed during decomposition of the diazo compound had an effect [11].

The chlorophenylation of (I) and (II) was accompanied by the evolution of heat. Under the optimal chlorophenylation conditions we found (reaction in aqueous acetone at pH 4-6 with adequate amounts of $CuCl_2$) the temperature had to be maintained at 0-5° for the normal course of the reaction. The liberation of nitrogen slowed at lower temperatures and chlorophenylation practically ceased. At higher temperatures, the Sandmeyer reaction became dominant. If the temperature was not maintained at the required level, but allowed to rise spontaneously, the rate of nitrogen liberation rapidly increased and there was strong evolution of heat. As a result, the process became explosive and the reaction mixture was converted to tarry and carbonaceous materials.

These investigations on the conditions and character of the chlorophenylation of butadiene (I) and isoprene (II) may be of interest not only for the development of a satisfactory method of synthesizing chlorophenylbutenes, but also for providing starting data for the elucidation of the mechanism of haloarylation of unsaturated compounds by aromatic diazo compounds, which has not been determined yet.

EXPERIMENTAL

The chlorophenylation of (I) and (II) was carried out by the procedure described previously [1, 2]. For this purpose, a solution of BDC in the minimal volume of water was prepared by diazotizing 0.2 mole of aniline with sodium nitrite. This solution of BDC (~90 ml) was gradually added from a dropping funnel with cooling to a solution of 0.25 mole of the diene in the organic solvent in a three-necked flask with a stirrer, thermometer, reflux condenser, and gas bubble counter. During the reaction, the temperature of the mixture was adjusted by external cooling so that nitrogen was evolved at 5-6 bubbles per second. The pH of the medium was determined periodically by placing drops of the mixture on universal indicator paper. Powdered CaO or MgO was added to the mixture when necessary to maintain the mixture at pH 4-6. When the evolution of nitrogen ceased, the organic part was extracted with ether, the extract dried with $CaCl_2$, and the chlorophenylbutene isolated by distillation. The $C_6H_5CH_2CH = CH_2CH_2Cl$ had b.p. 110-112° at 6 mm, d^{20}_4 1.054, $n^{20}D$ 1.5402; the $C_6H_5CH_2C)CH_3) = CHCH_2Cl$ had b.p. 119-121° at 13 mm, d^{20}_4 1.029, $n^{20}D$ 1.5340. These constants correspond to literature data [1, 2].

Chlorophenylation with the addition of various amounts of $CuCl_2$. The BDC solution was neutralized with $NaHCO_3$ powder to pH 4-6, the required amount of $CuCl_2$ added to it, and the mixture added to a solution of the diene in acetone. The chlorophenylbutene yields and reaction times in relation to the amounts of $CuCl_2$ used, are given in Table 1.

Chlorophenylation in the presence of CuCl. The reaction was carried out in a nitrogen atmosphere. To a mixture of the diene in 90 ml of acetone and 0.02 mole of CuCl was added an equal volume of BDC solution from 0.2 mole of aniline (pH 4-6). When the liberation of nitrogen was complete, from the upper, organic layer we isolated 11-12 g of chlorophenylbutenes, about 8 g of chlorobenzene, and about 4 g of benzene. The aqueous layer

and precipitate were transferred to a graduated flask, acidified with hydrochloric acid, and diluted to 500 ml. The Cu^{++} ions in the solution obtained were determined iodometrically [12]. We found an average of 0.90-0.92 g (70-73%) of Cu^{++} ions. In a control experiment with all the components except BDC and the same procedure we found 8% of Cu^{++} ions. Thus, ~65% of the monovalent copper was oxidized to divalent during the chlorophenylation.

Chlorophenylation with various organic solvents. The reaction with (I) was carried out in a volume of organic solvent equal to the volume of the partly neutralized BDC solution (~90 ml at pH 4-6), to which was added 0.04 mole of $CuCl_2$. In the reaction with (II), the ratio of water to organic solvent was 4 : 3 and the amount of $CuCl_2$ was 0.02 mole. The reaction temperature and chlorophenylbutene yields are given in Table 2.

Experiment in the absence of water. To a solution of 11 g of (I) and 3.4 g of $CuCl_2$ in 100 ml of anhydrous acetone was added 14.1 g of powdered BDC, prepared by the procedure in [13]. No evolution of nitrogen or other visible changes occurred when the mixture was stirred for 4 hr in the temperature range from 0 to 25°. When 20-25 ml of water was added to the mixture, appreciable evolution of nitrogen began at 7-10°. With the subsequent addition of a further ~70 ml of water, the reaction proceeded and was completed in the usual way. The yield of 4-chloro-1-phenyl-2-butene was 60%.

Chlorophenylation with media of various pH values. The solution of BDC was partly neutralized to a definite pH value, 0.02-0.04 mole of $CuCl_2 \cdot 2H_2O$ added, and the reaction then carried out with an acetone solution of the diene. The experimental results are given in Table 3. In the case of the reaction in the buffer solution (pH ~5), the BDC solution was added to a mixture of the diene and 0.48 mole of crystalline sodium acetate in 100 ml of acetone. The mixture was treated and the reaction products isolated in the usual way.

SUMMARY

The optimal conditions for the chlorophenylation of butadiene and isoprene with benzenediazonium chloride are as follows: 1) cupric chloride as catalyst; 2) acetone and acetonitrile as organic solvents in the presence of water; 3) medium pH of 4-6; 4) chlorophenylation temperature of 0-5°.

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BIS(β-CHLOROETHYL)AMINOMETHYLAZOBENZENES

II. p-ALKOXY-p'-BIS(β-CHLOROETHYL)AMINOMETHYLAZOBENZENES

AND SOME ANALOGOUS COMPOUNDS

A.K. Chizhov, K. V. Levshina, and S. I. Sergievskaya

In the synthesis of p-alkoxy-p'-bis(β- chloroethyl)aminomethylazobenzenes (IV), the starting material used was p-aminobenzyl-bis(hydroxyethyl)amine (I), the method of preparation of which was described in the previous communication [1]. The p-aminobenzyl-bis(β-hydroxyethyl)amine was diazotized, the diazonium salt formed coupled with phenol, and the p-hydroxy-p'-bis(β-hydroxyethyl)-aminomethylazobenzene (II) formed alkylated at the phenolic hydroxyl. The last stage of the synthesis consisted of replacement of the hydroxyls by chlorine in the hydroxyethyl groups of the compounds of type (III). The whole synthesis is represented by the following scheme:

$$H_2NC_6H_4CH_2N(CH_2CH_2OH)_2 \rightarrow HOC_6H_4N{=}NC_6H_4CH_2N(CH_2CH_2OH)_2 \rightarrow$$
$$\text{(I)} \qquad\qquad\qquad\qquad\qquad \text{(II)}$$
$$\rightarrow ROC_6H_4N{=}NC_6H_4CH_2N(CH_2CH_2OH)_2 \rightarrow ROC_6H_4N{=}NC_6H_4CH_2N(CH_2CH_2Cl)_2$$
$$\text{(III)} \qquad\qquad\qquad\qquad\qquad \text{(IV)}$$
$$R = CH_3,\ C_2H_5,\ n\text{-}C_3H_7,\ iso\text{-}C_3H_7,\ C_3H_5,\ n.\text{-}C_4H_9,\ iso\text{-}C_4H_9,\ n\text{-}C_5H_{11},\ iso\text{-}C_5H_{11}.$$
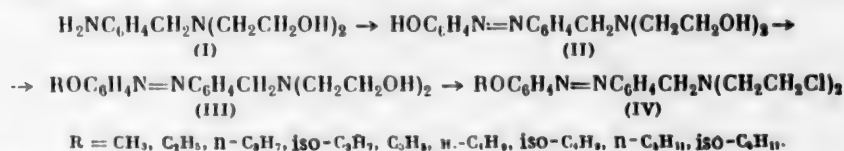
The phenolic hydroxyl in compound (II) was alkylated by three methods: A) methylation with dimethyl sulfate; B) treatment with alkyl bromides in alcoholic alkali; this method gave the best results when alkyl bromides with branched chains were used; C) alkylation with normal alkyl iodides in acetone in the presence of potassium carbonate. The allyloxy compound was also prepared by method C.

In the last stage of the synthesis, the p-alkoxy-p'-bis(β-chloroethyl)aminomethylazobenzene hydrochlorides formed by the reaction of compounds of type (III) with thionyl chloride could be purified by two methods: the hydrochloride was either recrystallized several times from anhydrous alcohol or the unpurified hydrochloride was first converted to the base and the latter then reconverted to the hydrochloride. The first method did not always give good results, especially in the case of compounds with lower alkyl radicals. In addition to alkoxy-bis(β-chloroethyl)-aminomethylazobenzenes, we also obtained the analogous compound without the alkoxyl group, namely, bis(β-chloroethyl)aminomethylazobenzene. This compound was obtained by condensation of nitrosobenzene with p-aminobenzyl-bis(β-hydroxyethyl)amine and subsequent replacement of the hydroxyl groups by chlorine in the bis(β-hydroxyethyl)-aminomethylazobenzene $C_6H_5N = N{-}C_6H_4CH_2N(CH_2CH_2OH)_2$, thus formed.

As the determination of the melting points of all the bis(β-chloroethyl)aminomethylazobenzene hydrochlorides synthesized required definite conditions and often involved decomposition, the infrared absorption spectra were plotted for complete characterization of these substances.*

The figure shows the infrared spectra of the hydrochlorides of the most typical compounds: bis(β-chloroethyl)-aminomethylazobenzene and p-butoxy-, p-isobutoxy-, and p-allyloxy-p'-bis(β-chloroethyl)aminomethylazobenzenes. The absorption frequencies of the other bis(β-chloroethyl)amine hydrochlorides synthesized are given in Table 1.

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* The infrared absorption spectra were plotted in the physical chemistry laboratory of the All-Union Chemicopharmaceutical Scientific Research Institute on an IKS-11 infrared spectrometer and an IKS-14 infrared spectrophotometer at room temperature. The substances were used in the crystalline state as a suspension in vaseline oil.
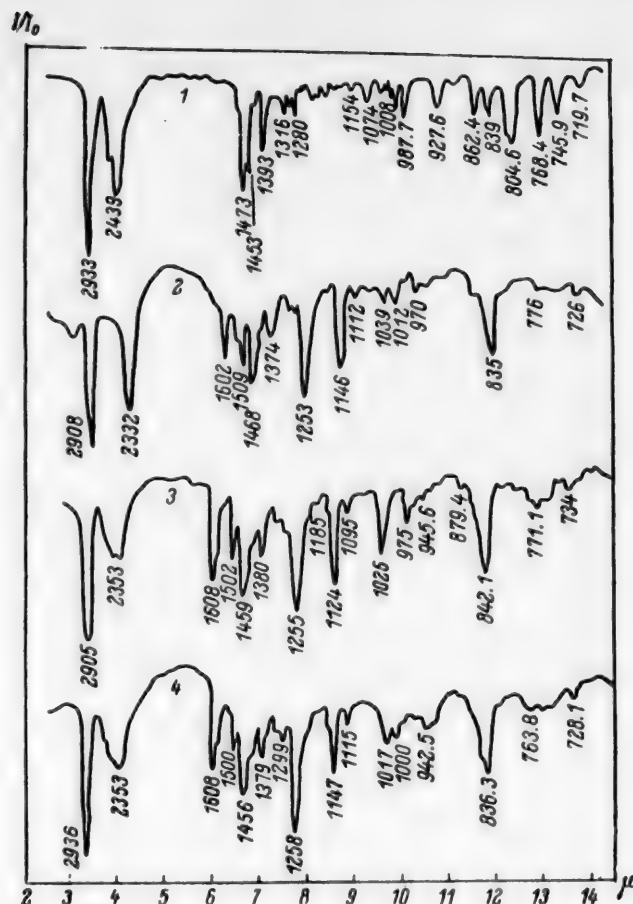
Infrared absorption spectra. 1) p'-bis(β-chloroethyl)aminometh-
ylazobenzene hydrochloride; 2) p-n-butoxy-p'-bis(β-chloroethyl)-
aminomethylazobenzene hydrochloride; 3) p-isobutoxy-p'-bis(β-
chloroethyl)aminomethylazobenzene hydrochloride; 4) p-allyloxy-
p'-bis(β-chloroethylaminomethylazobenzene hydrochloride.

EXPERIMENTAL

p-Hydroxy-p'-bis(β-hydroxyethyl)aminomethylazobenzene. A solution of 1.06 g of sodium nitrite in 26 ml of
water was added with vigorous stirring at 0° to a solution of 3.15 g of p-aminobenzyl-bis(β-hydroxyethyl)amine in
13.6 ml of 15.5% hydrochloric acid. The solution obtained was added dropwise with vigorous stirring at −5° to a
mixture of 1.4 g of phenol, 6 g of sodium bicarbonate, 21 ml of methanol, and 21 ml of water.

After the addition, the reaction mixture was stirred for a further hour and the yellow precipitate collected and
washed with water. Recrystallization from 25% aqueous alcohol yielded 3.7 g (79.0%) of p-hydroxy-p'-bis(β-hydroxy-
ethyl)aminomethylazobenzene with m.p. 140.5–142°. The golden scaly crystals were readily soluble in alcohol, ace-
tone, ether, and mineral acids and difficultly soluble in water, ligroin, and chloroform.

Found %: C 64.28; H 6.60; N 13.14. $C_{17}H_{21}O_3N$. Calculated %: C 64.76; H 6.71; N 13.31.

Alkylation of p-hydroxy-p'-bis(β-hydroxyethyl)aminomethylazobenzene. Method A. To a solution of 8 g of
p-hydroxy-p'-bis(β-hydroxyethyl)aminomethylazobenzene in a mixture of 60 ml of methanol and 26.6 ml of N so-
dium hydroxide solution was added 3.2 g of dimethyl sulfate dropwise with stirring in the cold. The reaction mixture
was stirred at room temperature for 3 hr, then heated under reflux at 70° for 35 min, cooled to room temperature,
treated with 16 ml of 20% aqueous ammonia solution, and again heated at 70° for 25 min. The cooled reaction mix-
ture was filtered and the filtrate evaporated in vacuum at 50°; the residue was a reddish-brown oil, consisting of the

TABLE 1. Infrared Absorption Spectra of p'-Bis(β-chloroethyl)aminomethylazobenzene Hydrochloride and Its Derivatives

$$R{-}\langle\bigcirc\rangle{-}N{=}N{-}\langle\bigcirc\rangle{-}CH_2{-}N{\big\langle}{\small{\begin{array}{l}CH_2CH_2Cl\\CH_2CH_2Cl\end{array}}}\quad HCl$$
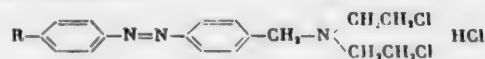
R	Frequency (cm^{-1})
CH_3O	2908, 2480, 1592, 1562, 1502, 1460, 1419, 1374, 1312, 1294, 1250, 1195, 1183, 1146, 1109, 1084, 1028, 993, 958, 942, 907, 892, 877, 839, 836, 816, 801, 758, 728
C_2H_5O	2882, 2332, 1592, 1512, 1460, 1435, 1374, 1306, 1283, 1243, 1195, 1183, 1162, 1146, 1115, 1084, 1039, 1017, 968, 958, 944, 918, 882, 865, 839, 832, 809, 786, 766, 748, 727
n.-C_3H_7O	2908, 2362, 1602, 1502, 1460, 1374, 1294, 1250, 1191, 1162, 1146, 1112, 1067, 1017, 978, 940, 918, 899, 877, 836, 816, 805, 769, 744, 723
iso-C_3H_7O	2908, 2525, 1592, 1513, 1468, 1374, 1312, 1294, 1250, 1225, 1181, 1146, 1119, 1087, 1017, 951, 892, 838, 796, 763, 758, 751
n-$C_5H_{11}O$	2908, 2354, 1602, 1513, 1485, 1419, 1403, 1374, 1298, 1260, 1150, 1114, 1087, 1055, 1019, 940, 918, 899, 877, 841, 816, 769, 748, 724
iso-$C_5H_{11}O$	2908, 2467, 1602, 1513, 1468, 1381, 1319, 1300, 1255, 1195, 1150, 1114, 1061, 1019, 968, 945, 918, 874, 839, 812, 781, 749

base p-methoxy-p'-bis(β-hydroxyethyl)aminomethylazobenzene, which was not purified further, but acidified to Congo red with an ether solution of hydrogen chloride. The ether was then removed in vacuum and the residue treated with thionyl chloride to prepare the bis(β-chloroethyl)amino compound.

Method B. To a mixture of 0.0159 mole of p-hydroxy-p'-bis(β-hydroxyethyl)aminomethylazobenzene, 48 ml of anhydrous alcohol, and 0.0161 mole of potassium hydroxide was added 0.0164 mole of alkyl bromide in 16 ml of anhydrous alcohol. The reaction mixture was heated on a vaseline bath at 85° for 5 hr and cooled, and the mineral precipitate removed by filtration. The filtrate was evaporated in vacuum and the residue treated with a small amount (about 30 ml) of water. The crystalline precipitate was collected and dried in a vacuum desiccator over calcium chloride. It was then dissolved in the minimal amount of acetone and a 5-fold volume of water added. The melting points of the substances thus isolated, the solubility in organic solvents and water, and analytical data on the p-alkoxy-p'-bis(β-hydroxyethyl)aminomethylazobenzenes are given in Table 2. The yield was 20.0 g (76%, calculated on the p-hydroxy-p'-bis(β-hydroxyethyl)aminomethylazobenzene taken).

Method C. A mixture of 0.0129 mole of p-hydroxy-p'-bis(β-hydroxyethyl)aminomethylazobenzene, 0.0142 mole of the alkyl iodide, 32 ml of anhydrous acetone, and 2 g of ground, calcined potassium carbonate was heated under reflux for 5 hr on a vaseline bath at 70°. The reaction mixture was then filtered, the filtrate evaporated in vacuum, and the residue treated with a small amount (50-60 ml) of water. The crystalline precipitate was washed with water. The substance obtained was dissolved in the minimal amount of acetone and reprecipitated with water. The yield was 67.7-75%.

p-Alkoxy-p'-bis(β-chloroethyl)aminomethylazobenzenes. A mixture of 0.0108 mole of p-alkoxy-p'-bis(β-hydroxyethyl)aminomethylazobenzene, 88 ml of anhydrous chloroform, and 0.215 mole of thionyl chloride was heated under reflux on a vaseline bath at 70° for 3 hr and then the thionyl chloride and chloroform removed in vacuum and the solid residue transferred to a filter with absolute ether, washed with absolute ether, and dried in a vacuum desiccator over phosphorus pentoxide, sodium hydroxide, and paraffin. The reaction product was purified by one of the methods presented below.

a) Recrystallization from anhydrous alcohol. The unpurified p-alkoxy-p'-N-di(β-chloroethyl)aminomethylazobenzene hydrochloride was dissolved with heating in the minimal amount of anhydrous alcohol (n-propanol in the case of p-n-propoxy compound), activated charcoal added, and the mixture boiled under reflux for 5-8 min and filtered through a fluted filter paper. The crystals of p-alkoxy-p'-bis(β-chloroethyl)aminomethylazobenzene which separated on cooling and standing were collected, washed on the filter with a small amount of dry ether, and dried

TABLE 2.

$$RO-\langle C_6H_4 \rangle-N=N-\langle C_6H_4 \rangle-CH_2-N\begin{cases} CH_2CH_2OH \\ CH_2CH_2OH \end{cases}$$

Sample No.	R	Preparation method	Melting point	Yield (%)	Molec-ular wt.	Empirical formula	Found (%) C	H	N	Calculated (%) C	H	N
1	H	Azo coupling of p-di-(β-hydroxyethyl)-aminomethylbenzene-diazonium chloride with phenol in aqueous methanol in the presence of sodium bicarbonate.	140.5—142°	84.8	315.36	$C_{17}H_{21}O_3N$	64.28	6.60	13.14	64.76	6.71	13.31
2	CH₃ **	Method A	—	—	—	$C_{18}H_{23}O_3N$	—	—	—	—	—	—
3	C_2H_5	Method C	93—95	73.8	343.414	$C_{19}H_{25}O_3N$	66.43	7.43	12.37	66.43	7.34	12.24
4	$n-C_3H_7$	Method B	102—104	76.0	357.44	$C_{20}H_{27}O_3N$	67.36	7.56	11.66	67.21	7.61	11.76
5	$iso-C_3H_7$	Method B	92—95	45.8	357.44	$C_{20}H_{27}O_3N$	66.85	7.48	12.30	67.21	7.61	11.76
6	$n-C_4H_9$	Method B	75—78 ***	70.8	371.466	$C_{21}H_{29}O_3N$	68.00	7.95	11.27	67.90	7.87	11.31
7	$iso-C_4H_9$	Method B	93—95	20.0	371.466	$C_{21}H_{29}O_3N$	67.25	7.80	12.87	67.90	7.87	11.31
8	$n-C_5H_{11}$	Method C	105—106	75.0	385.492	$C_{22}H_{31}O_3N$	67.93	8.16	11.37	68.54	8.10	10.90
9	$iso-C_5H_{11}$	Method B	87—89	24.2	385.492	$C_{22}H_{31}O_3N$	68.23	7.83	10.96	68.54	8.10	10.90
10	$CH_2=CH-CH_2$ ****	Method C	84—86	78.6	355.424	$C_{20}H_{25}O_3N$	67.79	7.25	12.33	67.58	7.09	11.82

• Solubility: readily soluble in CH_3OH, substances (sample No.) 3, 6, 7, 9, 10; in C_2H_5OH − 1, 3 -7, 9; in CH_3COCH_3 − 1, 3 -9; in $(C_2H_5)_2O$ − 1, 9; in mineral acids − 1; in $CHCl_3$ − 9. Moderately soluble in $(C_2H_5)_2O$ − 3, 7,; in $CH_3COOC_2H_5$ − 7; in $CHCl_3$ − 3; in C_6H_6 −7; in ligroin − 7. 0; Difficultly soluble in H_2O − 1, 3 -10; in C_6H_6 − 1, 3, 6; in $CHCl_3$ − 1, 6; in ligroin − 3, 6, 9; in benzine − 3.

• • The substance was not isolated in a pure form, but used for the next reaction.

• • • Appreciable decomposition occurred during slow melting.

• • • • The substance was purified by recrystallization from a water— methanol mixture.

TABLE 3

$$RO-\!\!\langle\bigcirc\rangle\!\!-N\!=\!N-\!\!\langle\bigcirc\rangle\!\!-CH_2-N\!\begin{smallmatrix}CH_2CH_2Cl\\CH_2CH_2Cl\end{smallmatrix} \cdot HCl$$

Sample No.	R	Method of isolation in a pure form	Melting point	Yield (%)	Molecular weight	Empirical formula	Found (%)				Calculated (%)			
							C	H	N	Cl	C	H	N	Cl
1	CH_3	Conversion to base, treatment with HCl in $(C_2H_5)_2O$	158–160°	25	402.751	$C_{18}H_{21}ON_3Cl_2 \cdot HCl$			10.24	26.91			10.43	26.41
2	C_2H_5	Conversion to base, treatment with HCl in $(C_2H_5)_2O$	155–157	25.6	416.777	$C_{19}H_{23}ON_3Cl_2 \cdot HCl$			9.93				10.09	25.51
		Recrystallization from anhydrous C_2H_5OH	179.5–181.5	35.4					10.07	25.03				
3	$n\text{-}C_3H_7$	Recrystallization from $n\text{-}C_3H_7OH$	185.5–187	68.0	430.803	$C_{20}H_{25}ON_3Cl_2 \cdot HCl$	56.03	5.87	9.93	24.62	55.75	6.08	9.75	24.69
		Recrystallization from C_2H_5OH	180–181	52.9			56.06	6.10	9.70	24.78	55.75	6.08	9. 5	24.69
4	$iso\text{-}C_3H_7$	Recrystallization from anhydrous C_2H_5OH	172–174	43.1	430.803	$C_{20}H_{25}ON_3Cl_2 \cdot HCl$			9.63	24.60			9.75	24.69
		Recrystallization from solution of HCl in C_2H_5OH with addition of HCl in $(C_2H_5)_2O$		88.2										
5	$n\text{-}C_4H_9$	Recrystallization from anhydrous C_2H_5OH	189–190	74.8	444.829	$C_{21}H_{27}ON_3Cl_2 \cdot HCl$	56.84	6.44	9.42	23.94	56.70	6.34	9.45	23.91
6	$iso\text{-}C_4H_9$	Recrystallization from anhydrous C_2H_5OH	178–180	54.8	444.829	$C_{21}H_{27}ON_3Cl_2 \cdot HCl$	56.26	6.38	10.04	24.14	56.70	6.34	9.45	23.91
7	$n\text{-}C_5H_{11}$	Recrystallization from mixture of anhydrous C_2H_5OH and $(C_2H_5)_2O$	170–172	47.5	458.855	$C_{22}H_{29}ON_3Cl_2 \cdot HCl$	57.40	6.61	9.13	22.96	57.58	6.59	9.15	23.18
8	$iso\text{-}C_5H_{11}$	Conversion to base, treatment with HCl in $(C_2H_5)_2O$	180–181	65.5	458.855	$C_{22}H_{29}ON_3Cl_2 \cdot HCl$	57.58	6.41	9.16	23.06	57.58	6.59	9.15	23.18
9	$CH_2=CH-CH_2$	Recrystallization from mixture of anhydrous C_2H_5OH and $(C_2H_5)_2O$	172–173	–	428.787	$C_{20}H_{23}ON_3Cl_3 \cdot HCl$			9.54	24.81			9.80	24.81
		Recrystallization from anhydrous C_2H_5OH	176–178	52.0					9.34	24.65			9.80	24.81

• The melting points were determined with a heating rate of 4° per min close to the melting point.

•• Solubility: readily soluble in CH_3OH, substances (sample No.)–1–6, 9; in C_2H_5OH–1, 4; in CH_3COCH–9; in $CH_3COOC_2H_5$–3; in $CHCl_3$– 3; in concentrated hydrochloric acid–1, 2. Moderately soluble in C_2H_5OH–2, 3, 5–9; in $(C_2H_5)_2O$–3, 8; in CH_3COCH_3–6, 7, 8; in $CH_3COOC_2H_5$–1, 8; in $CHCl_3$–4, 6, 8, 9; in C_2H_5–3; in concentrated hydrochloric acid–4. Difficulty soluble in H_2O–1–3, 5, 6, 9; in $(C_2H_5)_2O$–1, 2, 4–7, 9; in $CHCl_3$–1, 2; in C_6H_6–1, 2; in ligroin–5; in benzine–2.

TABLE 4

RO—⟨ ⟩—N=N—⟨ ⟩—CH₂—N⟨$_{CH_2CH_2Cl}^{CH_2CH_2Cl}$⟩

Structure: RO—C₆H₄—$N=N$—C₆H₄—CH_2—$N(CH_2CH_2Cl)(CH_2CH_2Cl)$

Sample No.	R	Melting point	Yield (%)	Molecular weight	Empirical formula	Found (%)				Calculated (%)			
						C	H	N	Cl	C	H	N	Cl
1	CH_3	Liquid*	25	365.286	$C_{18}H_{21}ON_3Cl_2$	59.04	5.55	10.86	19.57	59.03	5.78	11.47	19.36
2	C_2H_5	Liquid*	25.6	380.312	$C_{19}H_{23}ON_3Cl_2$			11.40	19.07			11.06	18.67
3	$n\text{-}C_3H_7$	54—56°	54.6	394.338	$C_{20}H_{25}ON_3Cl_2$	61.25	6.43	10.62	17.22	60.91	6.39	10.65	17.98
4	$iso\text{-}C_3H_7$	Decomposes at 160°	46.1	394.338	$C_{20}H_{25}ON_3Cl_2$			10.60	17.93			10.65	17.98
5	$n\text{-}C_4H_9$	82—84	40.5	408.364	$C_{21}H_{27}ON_3Cl_2$			10.50	17.34			10.29	17.37
6	$iso\text{-}C_4H_9$	Liquid*	54.0	408.364	$C_{21}H_{27}ON_3Cl_2$			10.69	17.85			10.29	17.37
7	$n\text{-}C_5H_{11}$	81—83 (rapid heating)	40.2	422.390	$C_{22}H_{29}ON_3Cl_2$	62.15	6.82	10.08	17.18	62.55	6.92	9.95	16.79
8	$iso\text{-}C_5H_{11}$	55—57	68.7	422.390	$C_{22}H_{29}ON_3Cl_2$	62.38	6.84	10.01	16.89	62.55	6.92	9.95	16.79
9	$CH_2=CH—CH_2$	42—44		392.322	$C_{20}H_{23}ON_3Cl_2$			10.31	18.17			10.71	18.08

Note:

1. The p-alkoxy-p'-N-di(β-chloroethyl)aminomethylazobenzenes were isolated in the pure form as bases by the action of 50% aqueous potassium carbonate solution on the unpurified hydrochloride. 2. Solubility: readily soluble in CH_3OH, substances (sample No.) — 2, 7, 8; in C_2H_5OH—7, 8; in $(C_2H_5)_2O$ 7, 8; in $CHCl_3$—1, 5, 7, 8; in C_6H_6—1, 5—8; in heavy benzine—1. Moderately soluble in CH_3OH—5; in C_2H_5OH—2; in $(C_2H_5)_2O$—1, 5; in CH_3COCH_3—4, 5; in $CH_3COOC_2H_5$—4; in $CHCl_3$—2, 3, 4; in $C_2H_4Cl_2$—2; in C_6H_6—2—4, 9. Difficultly soluble in H_2O—1. 2: in $(C_2H_5)_2O$—2; in ligroin—4, 5; in benzine—2, 7, 8, —3.

The asterisks indicate cases where crystals were deposited on prolonged standing.

in a vacuum desiccator over phosphorus pentoxide, sodium hydroxide, and paraffin. The yield was 35.4-68%, calculated on the starting p-alkoxy-p'-bis(β-hydroxyethyl)aminomethylazobenzene. The melting points, solubilities, and analytical data of the compounds purified in this way are given in Table 3.

b) Conversion of p-alkoxy-p'-bis(β-chloroethyl)aminomethylazobenzene hydrochlorides to the bases and preparation of hydrochlorides from the latter. The unpurified p-alkoxy-p'-bis(β-chloroethyl)aminomethylazobenzene hydrochloride, which was obtained in close to quantitative yield, was treated with excess 50% aqueous potassium carbonate solution and the liberated base extracted with thiophene-free benzene. The benzene extract was dried with potassium carbonate, filtered, and evaporated in vacuum with protection against atmospheric carbon dioxide. The residue was the analytically pure base, p-alkoxy-p'-bis(β-chloroethyl)aminomethylazobenzene. The yield was 25.6-68.7%, calculated on the p-alkoxy-p'-bis(β-hydroxyethyl)aminomethylazobenzene. The melting points, solubilities, and analytical data of the bases obtained are given in Table 4.

The base isolated was dissolved in absolute ether and acidified to Congo red with excess of hydrogen chloride in absolute ether. The crystalline precipitate of p-alkoxy-p'-bis(β-chloroethyl)aminomethylazobenzene hydrochloride was collected, washed with absolute ether, and dried in a vacuum desiccator over phosphorus pentoxide, sodium hydroxide, and paraffin. The yield was 25.6-65.5%.

p-Bis(β-chloroethyl)aminomethylazobenzene hydrochloride. A solution of 5 g of p-aminobenzyl-bis(β-hydroxyethyl)amine in 10 ml of glacial acetic acid was added at room temperature with stirring to a solution of 2.93 g of nitrobenzene in 20 ml of glacial acetic acid. The reaction mixture was stirred at room temperature for 3 hr and diluted with 150 ml of water and excess aqueous ammonia solution added. The liberated base was extracted with ether and the ether extract dried with potassium carbonate, filtered, and evaporated in vacuum. To the oily residue was added 100 ml of dry chloroform and 16.9 ml of thionyl chloride. The reaction mixture was heated at 65° for 3 hr, the chloroform and thienyl chloride removed in vacuum, and the solid violet residue transferred to a filter with absolute ether. The substance obtained was dissolved in the minimal amount of anhydrous alcohol, the solution heated with activated wood charcoal and filtered, and a 4-fold volume of absolute ether added to the cooled solution. The crystals liberated were collected and dried in a vacuum desiccator over phosphorus pentoxide, sodium hydroxide, and paraffin. The yield was 1.5 g (16.9%) and the m.p. 161-163°. The brownish gray crystals were readily soluble in methanol, ethanol, and chloroform, moderately soluble in ethyl acetate, and difficultly soluble in ether and water.

Found %: N 11.07, 11.47; Cl 28.93, 28.70. $C_{17}H_{19}N_3Cl_2 \cdot HCl$. Calculated %: N 11.27; Cl 28.52.

The free base, p-bis-(β-chloroethyl)aminomethylazobenzene, was obtained from the hydrochloride by the method described for the analogous alkoxy compounds. It formed an oil which crystallized on prolonged standing and was readily soluble in benzene, chloroform, and ethyl acetate.

Found %: N 12.32; Cl 20.98, 21.09. $C_{17}H_{19}N_3Cl_2$. Calculated %: N 12.50; Cl 21.09.

SUMMARY

1. p-Hydroxy-p'-bis(β-hydroxyethyl)aminomethylazobenzene and p-bis(β-chloroethyl)aminomethylazobenzene were prepared.

2. Alkylation of the phenolic hydroxyl in p-hydroxy-p'-bis(β-hydroxyethyl)aminomethylazobenzene yielded a series of p-alkoxy-p'-bis(β-hydroxyethyl)aminomethylazobenzenes with different alkyl radicals; three alkylation methods are described.

3. A series of p-alkoxy-p'-bis(β-chloroethyl)aminomethylazobenzenes in the form of bases and hydrochlorides with different alkyl radicals in the alkoxyl groups were prepared.

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CYCLOSERINE AND RELATED COMPOUNDS

XIII. SOME 4-AMINOPYRAZOLIDONES-3

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The synthesis of various analogs of the antituberculous antibiotic cycloserine (I) made it possible to express a definite point of view on the mechanism of the antibiotic action of cycloserine [1]. For a more thorough study of this action, it seemed interesting to synthesize a new type of analog of cycloserine. All the analogs obtained up to now are derivatives of isoxazolidone-3 [2-6]. It is natural that 4-aminopyrazolidones-3 (II), which are aza analogs of cycloserine, attract great attention.
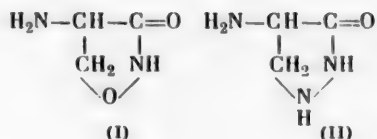
The present communication is devoted to a study of the most efficient routes to the synthesis of 4-amino-pyrazolidones-3. The most convenient synthesis method appeared to be cyclization of hydrazides of α-acylamino-acrylic acids (III), which, in their turn, could be obtained by the reaction of unsaturated azlactones (IV) with hydrazine.
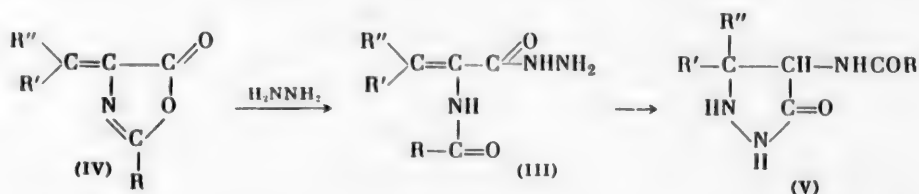
The reaction of azlactones with hydrazine has been studied by several authors [7, 8], but only Wilson [9] and Stodola [10] determined the structure of the products from the reaction of 2-phenyl-4-benzylidene- and 2-phenyl-4-isopropylideneoxazolone-5 with hydrazine. It was shown that the hydrazides of the corresponding α-benzoyl-aminoacrylic acids were formed. The latter were readily cyclized by heating to give 4-acylaminopyrazolidones-3 (V).

We made a detailed study of the reaction of unsaturated azlactones with hydrazine and the cyclization of the reaction products formed. It was found that 2-aryl-4-arylidene- and 2-aryl-4-alkylideneoxazolones-5 (IV, R = C_6H_5) react readily with hydrazine in alcohol to give high yields of hydrazides of α-benzoylamino- β-aryl(or β-alkyl) acrylic acids (III, R = C_6H_5). Heating the latter or the direct reaction of azlactones with hydrazine with heating led to cyclization and the formation of 4-benzoylaminopyrazolidones-3. In the case of 2-methyl-4-arylideneoxazolones-3 (IV, R = CH_3), cyclization of the hydrazides to the corresponding 4-acetylaminopyrazolidones-3 proceeded so readily that the hydrazide of α-acetylaminocinnamic acid (III, R = CH_3) could be isolated only if the reaction was carried out with cooling. The hydrazides of α-acetyl(or α-benzoyl)amino-p-nitrocinnamic acid (VI) were more resistant to cyclization. When they were heated with hydrazine, together with cyclization there was reduction of the nitro group to an amino group to form as a result 4-acylamino-5-p-aminophenylpyrazolidones-3 (VII).
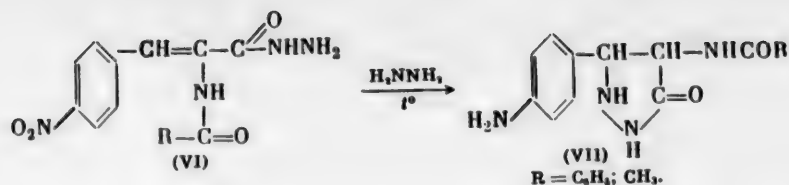
The synthesis could be carried out with azlactones containing heterocyclic radicals. Thus, 4-acetylamino-5-(α-furyl)-pyrazolidone-3 was prepared.

TABLE 1

R'	R"	R	Melting point	% N		Yield (%)	Notes
				found	calcu-lated		
C_6H_5	H	C_6H_5	153—154°	14.20	14.04	84	Monohydrate: literature data: m.p. 151-153° [4]
$CH_3OC_6H_4$	H	C_6H_5	141—144	13.14	12.80	84	Monohydrate
$CH_2O_2C_6H_3$	H	C_6H_5	146—147	12.28	12.25	81	Monohydrate
$O_2NC_6H_4$	H	C_6H_5	174—175	16.20	16.28	82	Monohydrate
$(CH_3)_2NC_6H_4$	H	C_6H_5	191—192	16.37	16.37	90	Monohydrate
CH_3	H	C_6H_5	184—186	19.50	19.17	70	
CH_3	CH_3	C_6H_5	192—194	18.12	18.03	72	
$(CH_2)_5$	H	C_6H_5	195—196	15.26	15.37	74	

Cycloserine acylated at the amino group is known to have no antibacterial activity. The next problem was therefore the hydrolysis of the acyl group in the acylamino derivatives (V). This was complicated by the relatively low resistance to hydrolysis of the pyrazolidone ring itself. It was found that hydrazides of β-substituted α-acyl-aminoacrylic acids are completely hydrolyzed by a methanol solution of hydrogen chloride to give a quantitative yield of hydrazine dihydrochloride. Though 4-benzoylaminopyrazolidones-3 are much more stable under these conditions and are decomposed only by boiling with 15% hydrochloric acid, only very small amounts of 4-aminopy-razolidones-3 could be detected among the reaction products. It was not possible to debenzoylate 4-benzoylamino-pyrazolidones-3 in acceptable yield in either acid or alkaline media.

As is well-known, the acetamido group is hydrolyzed much more readily than the benzamido group and therefore 4-acetylaminopyrazolidones-3 could be deacetylated by treatment of the latter (V, R = CH_3) with a methanol solution of hydrogen chloride.

TABLE 2

$$R-CONH-CH-C\overset{O}{\underset{\underset{NH}{N}}{<}}$$
$$\underset{R''}{\overset{R'}{|}}C$$

R'	R''	Melting point	%C found	%C calculated	%H found	%H calculated	%N found	%N зачислет	Yield (%)	Notes
C₆H₅	H	226—227°	67.96	68.31	5.37	5.38	15.05	15.05	76	Literature data: m.p. 228° [10]
CH₃OC₆H₄	H	224—225	65.46	65.57	5.48	5.48	13.48	13.50	74	
CH₂O₂C₆H₃	H	229—230	62.80	62.75	4.62	4.62	13.02	12.91	81	
H₂NC₆H₄	H	204—205(decomp.)	65.06	65.00	5.46	5.42	19.37	19.00	72	
(CH₃)₂NC₆H₄	H	224—226(decomp.)	64.53	64.25	6.48	6.48	16.44	16.37	84	Monohydrate
CH₃	H	119—120	60.35	60.35	5.98	5.94	19.19	19.17	69	
CH₃	CH₃	139—140	—	—	—	—	18.07	18.00	64	Literature data: m.p. 139 [9]
(CH₂)₅	H	189—190	66.02	66.00	7.01	6.96	15.45	15.37	71	
C₆H₅	H	171—172	60.70	60.35	5.95	5.94	19.35	19.20	70	
CH₃OC₆H₄	H	155—156	56.13	56.16	6.18	6.08	16.40	16.50	72	
(CH₃)₂NC₆H₄	H	180	—	—	—	—	20.70	21.04	77	
⟨morpholine ring⟩	H	122—124	47.73	47.75	5.66	5.77	18.18	18.49	70	Monohydrate

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The 5-substituted 4-aminopyrazolidones-3, which are close analogs of cycloserine, formed by this treatment were isolated in yields of 50-60% and used for chemotherapeutic testing, the results of which will be published separately.

As regards the preparation of azacycloserine itself (II), the synthesis was found to be very complicated because of the difficulty of preparation and the lability of 2-phenyl-4-methyleneoxazolone-5. However, the N-benzoyl derivative, 4-benzamidopyrazolidone-3, could be obtained in very low yield by two other methods: 1) condensation of the ester of N-benzoyl-β-chloroalanine with hydrazine and 2) treatment of α-benzoylaminoacrylic ester with hydrazine hydrate.

$$Cl-CH_2-CH-COOCH_3 \qquad \xrightarrow{H_2NNH_2} \qquad C_6H_5CONH-CH-C\overset{O}{<} \qquad \leftarrow \qquad CH_2=C-C\overset{O}{<}OCH_3$$
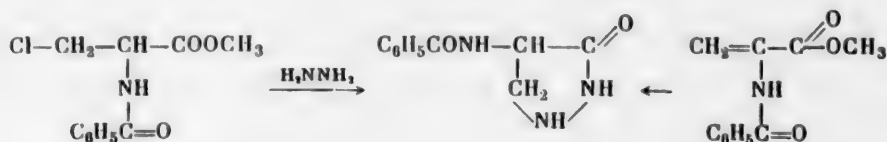
Removal of the benzoyl group and conversion into azacycloserine itself could not be achieved. The synthesis of azacycloserine by a different method and its properties will be published in the next communication.

EXPERIMENTAL

Hydrazides of α-benzoylamino-β-aryl- or β-alkylacrylic acids. To a suspension of 0.02 mole of 2-phenyl-4-arylidene- or 2-phenyl-4-alkylideneoxazolone-5 in 40 ml of alcohol at room temperature was added 6 ml of 85% hydrazine hydrate and the mixture stirred until the oxazolone dissolved completely. After 24 hr, the precipitated hydrazide was collected, washed with cold alcohol and ether, and recrystallized from alcohol. The constants, analyses, and yields of the hydrazides of α-benzoylamino-β-aryl- and alkyl-acrylic acids are given in Table 1.

Hydrazide of α-acetylamino-β-phenylacrylic acid. To a suspension of 4 g of 2-methyl-4-benzylideneoxazolone-5 in 20 ml of alcohol at 0° was added 4 ml of 85% hydrazine hydrate; the oxazolone dissolved after a few minutes and then a crystalline substance separated. The yield was 3 g (75%) and the m.p. 135-136° (from alcohol).

Found %: N 17.96. $C_{11}H_{13}O_2N_3 \cdot H_2O$. Calculated %: N 18.20.

After being dried over phosphorus pentoxide at 60° in vacuum, the substance had m.p. 156-157°.

Found %: N 19.20. $C_{11}H_{13}O_2N_3$. Calculated %: N 19.26.

Hydrazide of α-acetylamino-β-(p-nitrophenyl)-acrylic acid. To a suspension of 4.6 g of 2-methyl-4-(p-nitrophenylidene)-oxazolone-5 in 40 ml of alcohol was added 6 ml of 85% hydrazine hydrate and the mixture stirred at room temperature for 2.5 hr and left overnight. The subsequent treatment was as in the previous experiment. The yield was 4.42 g (79%) and the m.p. 166-167°.

Found %: C 47.32; H 4.90; N 19.50. $C_{11}H_{12}O_4N_4 \cdot H_2O$. Calculated %: C 47.25; H 4.99; N 19.70.

4-Benzoylamino-5-aryl- and 4-benzoylamino-5-alkylpyrazolidones-3. A mixture of 0.04 mole of 2-phenyl-4-arylidene- or 2-phenyl-4-alkylideneoxazolone-5, 15 ml of 85% hydrazine hydrate, and 55 ml of alcohol was boiled on a water bath for 1.5 hr and then left overnight in a refrigerator. If the pyrazolidone precipitated then it was collected and the filtrate diluted with cold water to give a further portion of the substance. If the pyrazolidone did not precipitate, the solution was evaporated to dryness in vacuum and the residue recrystallized from alcohol. The constants, analyses, and yields of the 4-benzoylamino-5-aryl- and alkylpyrazolidones-3 obtained are given in Table 2.

4-Acetylamino-5-aryl- and 4-acetylamino-5-(α-furyl)-pyrazolidones-3. A mixture of 0.02 mole of 2-methyl-4-arylidene- or 2-methyl-4-(α-furylidene)-oxazolone-5, 7 ml of 85% hydrazine hydrate, and 30 ml of alcohol was boiled for 40 min and left overnight in a refrigerator. The crystalline precipitate was collected, washed with cold alcohol and ether, and recrystallized from alcohol. The constants, analyses, and yields of the 4-acetylamino-5-aryl- and 5-(α-furyl)-pyrazolidones-3 obtained are given in Table 2.

TABLE 3

B	R'	R	n	Starting azlactone	Reagent	Melting point	%N found	%N calculated	%Cl found	%Cl calculated	Yield (%)
C_6H_5	H	C_6H_5CO	1	4-benzoyl	HCl/CH$_3$OH	223–224°	13.24	13.22	11.49	11.50	80
CH$_3$	CH$_3$	C_6H_5CO	1	4-benzoyl	HCl/CH$_3$OH	200–201	14.87	15.00	13.78	13.78	76
C_6H_5	H	H	1	4-benzoyl	15% HCl	113 (decomp.)	20.40	19.99	16.62	16.73	Low
C_6H_5	H	H	2	4-acetyl	HCl/CH$_3$OH	120 (decomp.)	16.17	16.80	27.17	28.35	52
CH$_3$OC$_6$H$_4$	H	H	2	4-acetyl	HCl/CH$_3$OH	115 (decomp.)	14.77	14.90	25.38	25.30	54
(CH$_3$)$_2$NC$_6$H$_5$	H	H	3	4-acetyl	HCl/CH$_3$OH	183 (decomp.)	17.14	17.00	32.71	32.22	60
[furyl]	H	H	2	4-acetyl	HCl/CH$_3$OH	86 (decomp.)	17.45	17.49	29.30	29.50	51
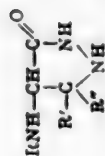
4-Benzoylaminopyrazolidone-3. A) From methyl ester of N-benzoyl-β-chloroalanine. To a solution of 4.6 g of the methyl ester of N-benzoyl-β-chloroalanine in 80 ml of absolute methanol was added 2.1 g of hydrazine dihydrochloride. Then with stirring, a solution of sodium methylate (from 1.4 g of sodium and 45 ml of methanol) was added at such a rate that the temperature did not rise above 15°. After the sodium methylate had been added, the mixture was stirred at room temperature for a further 2 hr and then boiled for 2 hr. The cooled mixture was filtered to remove sodium chloride, the filtrate evaporated to dryness in vacuum, the residue extracted with anhydrous alcohol, the extract evaporated to dryness, and the residue again extracted with anhydrous alcohol. To the extract was added excess ether and the precipitate recrystallized. The yield was 0.4 g 10%) and the m.p. 107-109° (from anhydrous alcohol).

Found %: C 58.34; H 5.66; N 19.61. $C_{10}H_{11}O_2N_3$. Calculated %: C 58.51; H 5.37; N 20.05.

B) From methyl ester of α-benzoylaminoacrylic acid. A mixture of 1.8 g of the methyl ester of α-benzoylamino-acrylic acid, 1 ml of 85% hydrazine hydrate, and 5 ml of anhydrous alcohol was boiled for 3 hr and the alcohol and excess hydrazine hydrate evaporated in vacuum. The product was treated as described above and the yield was 0.1 g and the m.p. 106-109°.

Action of hydrogen chloride in methanol on 4-benzoyl-amino-5-aryl- and 4-benzoylamino-5,5-dimethylpyrazolidones-3. A solution of 0.01 mole of the pyrazolidone in 50 ml of anhydrous methanol at 10-20° was saturated with dry hydrogen chloride and left at room temperature for 3 hr. The mixture was evaporated to 2 ml at 30° and ether added to the residue. The precipitate was collected, washed with cold methanol and ether, and recrystallized from alcohol. The constants and yields are given in Table 3.

Action of hydrogen chloride in methanol on 4-acetyl-amino-5-aryl- and 5-furylpyrazolidones-3. A solution of 0.01 mole of the pyrazolidone in 40 ml of anhydrous methanol at 10-15° was saturated with dry hydrogen chloride and left at room temperature for 2 hr, the excess hydrogen chloride flushed out with nitrogen, and the solution evaporated in high vacuum. The residue, which crystallized when triturated with dry ether, was dissolved in methanol and ether added to the solution. The precipitate was collected and washed with ether. The constants, analyses, and yields of the 4-amino-5-substituted pyrazolidone-3 dihydrochlorides obtained are given in Table 3.

Action of hydrochloric acid on 4-benzoylamino-5-phenylpyrazolidone-3. A mixture of 15 g of 4-benzoylamino-5-phenylpyrazolidone-3, 15 ml of 15% hydrochloric acid, and 15 ml of water was boiled for 2.5 hr and evaporated to dryness. The residue obtained was dried in vacuum over alkali and extracted with boiling anhydrous isopropanol, the extract cooled, and the precipitate recrystallized from isopropanol. The yield of 4-amino-5-phenylpyrazolidone-3 hydrochloride was 0.5 g.

SUMMARY

1. A series of hydrazides of α-acylamino-β-substituted acrylic acids and 4-acylamino-5-substituted pyrazolidones-3 were obtained.

2. A method was developed for synthesizing 4-amino-5-aryl- and (α-furyl)-pyrazolidones-3.

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CHLOROMETHYLATION OF TRIALKYLBENZYLSILANES
AND SOME CONVERSIONS OF CHLOROMETHYLBENZYL-
TRIALKYLSILANES

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We demonstrated that it is possible to apply chloromethylation to organosilicon compounds in 1958 [1]. Somewhat later, K. A. Andrianov, A. A. Zhdanov, and V. A. Odinets [2] described the preparation of chloromethylbenzyldimethylchlorosilane by chloromethylation of benzyldimethylchlorosilane.

In the present work we studied the chloromethylation of a series of trialkylbenzylsilanes, which were obtained by the reaction of benzylmagnesium chlorides with trialkylhalosilanes.

$$C_6H_5CH_2MgCl + R_3SiX \rightarrow R_3SiCH_2C_6H_5 + MgClX;$$

$$R_3SiCH_2C_6H_5 + HCHO + HCl \xrightarrow{ZnCl_2} R_3SiCH_2C_6H_4CH_2Cl + H_2O,$$

$$R = CH_3; \ C_2H_5, \ C_3H_7, \ C_4H_9.$$
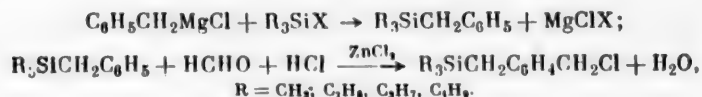
Hydrolysis of the chloromethyl derivatives of trialkylbenzylsilanes yielded a series of oxygen-containing organosilicon compounds and from organomagnesium compounds of the chloromethyl derivatives we obtained a series of silicohydrocarbons.

The trialkylbenzylsilanes were chloromethylated in an aqueous medium with 35% formalin at 70-85° and in carbon tetrachloride with paraformaldehyde at 50-55°. Zinc chloride was used as the catalyst.

Chloromethyl derivatives of trimethyl- and triethylbenzylsilanes were obtained by chloromethylation of the latter both in an aqueous medium and in carbon tetrachloride. In the chloromethylation of trimethyl- and triethylbenzylsilanes under identical conditions in an aqueous medium for 16 hr, chloromethylbenzyltrimethylsilane was obtained in 54% yield, while the yield of chloromethylbenzyltriethylsilane was only 19% (calculated on the trialkylbenzylsilane used for the reaction). In the chloromethylation of trimethyl- and triethylbenzylsilanes in carbon tetrachloride, the yield of the chloromethyl derivatives in both cases was of the order of 30%. In the chloromethylation of tripropylbenzylsilane in carbon tetrachloride, chloromethylbenzyltripropylsilane was obtained in 8.5% yield, while tributylbenzylsilane was not chloromethylated under these conditions. Chloromethylbenzyltributylsilane was obtained in 11% yield by chloromethylation of tributylbenzylsilane in glacial acetic acid with paraformaldehyde at 80°. Consequently, the chloromethylation of benzyltrialkylsilanes becomes more difficult as the size of the alkyl radical increases.

The properties of the chloromethylbenzyltrialkylsilanes obtained are given in Table 1.

Hydrolysis of the chloromethyl derivatives of trimethyl- and triethylbenzylsilanes by heating in an aqueous medium in the presence of calcium carbonate formed the corresponding alcohols, which condensed to ethers on heating.

$$R_3SiCH_2C_6H_4CH_2Cl + H_2O \xrightarrow{-HCl} R_3SiCH_2C_6H_4CH_2OH$$

$$2R_3SiCH_2C_6H_4CH_2OH \xrightarrow{-H_2O} R_3SiCH_2C_6H_4CH_2-O-CH_2C_6H_4CH_2SiR_3$$

$$R = CH_3, \ C_2H_5.$$
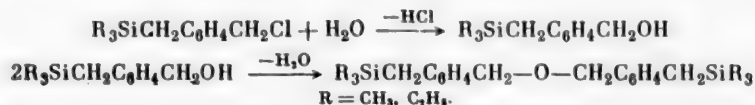
TABLE 1. Properties of Chloromethylbenzyltrialkylsilanes

Compound	Preparation medium	Boiling point (pressure in mm)	d_4^{20}	n_D^{20}	MR_D	
					found	calcu-lated
$(CH_3)_3SiCH_2C_6H_4CH_2Cl$ {	H_2O CCl_4	96—98° (5) 95—96 (4)	0.9980 1.0170	1.5220 1.5268	65.02 64.31	} 63.99
$(C_2H_5)_3SiCH_2C_6H_4CH_2Cl$ {	H_2O CCl_4	139—141 (3) 138—139 (3)	0.9910 0.9951	1.5250 1.5258	78.80 78.59	} 77.88
$(C_3H_7)_3SiCH_2C_6H_4CH_2Cl$	CCl_4	155—157 (3)	0.9666	1.5158	92.74	91.77
$(C_4H_9)_3SiCH_2C_6H_4CH_2Cl$	CH_3COOH	191—194 (4)	0.9570	1.5024	104.62	105.66

In addition to the corresponding trialkylmethylbenzylsilanes, the reduction of trimethyl- and triethylbenzyl-silanes through their organomagnesium compounds yielded condensation products of the chloromethylbenzyltrialkyl-silanes.

$$R_3SiCH_2C_6H_4CH_2Cl + Mg \rightarrow R_3SiCH_2C_6H_4CH_2MgCl,$$
$$R_3SiCH_2C_6H_4CH_2MgCl + HCl \rightarrow R_3SiCH_2C_6H_4CH_3 + MgCl_2,$$
$$R_3SiCH_2C_6H_4CH_2MgCl + R_3SiCH_2C_6H_4CH_2Cl \longrightarrow R_3SiCH_2C_6H_4CH_2-CH_2C_6H_4CH_2SiR_3$$
$$R = CH_3, C_2H_5.$$
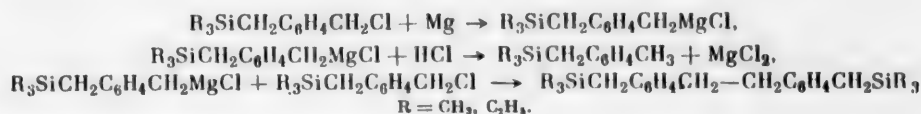
The reaction of the organomagnesium compounds of trimethyl- and triethyl(chloromethylbenzyl)silanes with trialkylhalosilanes yielded the corresponding silicohydrocarbons.

$$R_3SiCH_2C_6H_4CH_2Cl + Mg \rightarrow R_3SiCH_2C_6H_4CH_2MgCl$$
$$R_3SiCH_2C_6H_4CH_2MgCl + R_3SiX \rightarrow R_3SiCH_2C_6H_4CH_2SiR_3 + MgClX$$
$$R = CH_3, C_2H_5; \qquad X = Cl, Br.$$
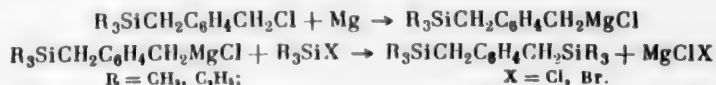
Condensation products of the chloromethylbenzyltrialkylsilanes were also isolated in this case.

The properties of the silicohydrocarbons and oxygen-containing compounds obtained from trimethyl- and triethyl(chloromethylbenzyl)silanes are given in Table 2.

In a previous communication [3], we described the synthesis of organosilicon compounds from chloromethyl derivatives of alkylbenzenes. The quantitative ratio of the isomers in the organosilicon compounds obtained was determined by oxidizing them by the method of I. N. Nazarov and A. V. Semenovskii [4], which they used to deter-mine the composition of a mixture of chloromethylalkylbenzene isomers.

In the present work, this method was used to determine the ratio of isomers in the chloromethyl derivatives of trialkylbenzylsilanes. Oxidation of the chloromethylbenzyltrialkylsilanes obtained in carbon tetrachloride established that the chloromethylation of trimethylbenzylsilane formed 70% of the para-isomer, chloromethylation of triethyl-benzylsilane formed 75% of the para-isomer, and chloromethylation of tripropylbenzylsilane formed 98% of the para-isomer. In chloromethylation in an aqueous medium, the amount of the para-isomer for trimethyl- and triethyl-benzylsilane was more than 90%. This explains the difference in the properties of the trimethyl- and triethyl(chloro-methylbenzyl)silanes obtained in an aqueous medium and in carbon tetrachloride (Table 1).

The results of determining the para- and ortho-isomers from the chloromethylation of trimethyl- and triethyl-benzylsilanes agree well with Raman spectral data for methylbenzyltrimethyl- and methylbenzyltriethylsilanes.[*]

EXPERIMENTAL

A. Chloromethylation of Trialkylbenzylsilanes

1. Chloromethylation of trimethylbenzylsilane. Experiment 1a. Hydrogen chloride was passed through a mixture of 110 g of trimethylbenzylsilane, 100 g of 35% formalin, and 15 g of zinc chloride with stirring at room

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[*] The spectra were plotted by Yu. P. Egorov.

TABLE 2. Properties of Silicohydrocarbons and Oxygen-Containing Organosilicon Compounds

Compound	Boiling point (pressure in mm)	d_4^{20}	n_D^{20}	M found	M calculated	MR_D found	MR_D calculated	Found C	Found H	Found Si	Calc. C	Calc. H	Calc. Si
$(CH_3)_3SiCH_2C_6H_4CH_3$	80.5—81° (8)	0.8685	1.4960	—	—	59.97	59.15	74.38 74.36	10.27 10.17	15.11 15.04	74.10	10.17	15.73
$(CH_3)_3SiCH_2C_6H_4CH_2OH$	114—116 (3)	0.9625	1.5180	—	—	61.17	60.70						
$[(CH_3)_3SiCH_2C_6H_4CH_2]_2O$	M.p. 65°	—	—	365, 368	370.6	—	—	71.43 71.44	9.34 9.15	15.16 15.00	71.29	9.24	15.14
$(CH_3)_3SiCH_2C_6H_4CH_2Si(CH_3)_3$	M.p. 58-58.5°	—	—	245, 248	250.5	—	—	67.27 67.32	10.46 10.40	21.75 22.04	67.14	10.46	22.40
$(CH_3)_3SiCH_2C_6H_4CH_2CH_2C_6H_4CH_2Si(CH_3)_3$	M.p. 68°	—	1.5055	347, 350	354.6	—	—	74.68 74.69	9.67 9.88	14.89 14.95	74.51	9.66	15.83
$C_2H_5)_3SiCH_2C_6H_4CH_3$	102 (2)	0.8968				73.51	72.68	76.52 76.52	10.87 10.86	12.36 12.56	76.30	10.97	12.73
$[(C_2H_5)_3SiCH_2C_6H_4CH_2]_2O$	235—237 (2)	0.9633	1.5305	447, 445	454.7	145.94	145.00	74.09 73.98	10.21 10.35	11.54 11.78	73.95	10.20	12.34
$C_2H_5)_3SiCH_2C_6H_4CH_2CH_2Si(C_2H_5)_3$	170—172 (2)	0.8960	1.5050	327, 329	334.6	110.77	109.73	72.02 72.03	11.48 11.44	16.43 16.22	71.78	11.45	16.77
$C_2H_5)_3Si:CH_2C_6H_4CH_2C_6H_4CH_2Si(C_2H_5)_2$	233—236 (2)	0.5300	0.9392	430, 432	438.7	144.29	143.23	76.92 76.94	10.70 10.58	12.74 12.36	76.64	10.57	12.79

temperature for 1 hr and then at 65-70° for 16 hr. The washed and dried reaction products were fractionated. We obtained 77.6 g (54.2%) of chloromethylbenzyltrimethylsilane.

B.p. 96-98° (5 mm), d_4^{20} 0.9980, n_D^{20} 1.5220, MR_D 65.02; calc. 63.99.

Experiment 2a. Hydrogen chloride was passed through a mixture of 70 g of trimethylbenzylsilane, 30 g of paraformaldehyde, 30 g of zinc chloride, and 300 ml of carbon tetrachloride with stirring at 50-55° for 3 hr. The cooled reaction mixture was washed until neutral, dried with calcium chloride, and fractionated. We obtained 27 g (30%) of chloromethylbenzyltrimethylsilane.

B.p. 95-96° (4 mm), d_4^{20} 1.0170, n_D^{20} 1.5268, MR_D 64.31; calc. 63.99.

2. Chloromethylation of triethylbenzylsilane. Experiment 1b. Hydrogen chloride was passed through a mixture of 150 g of triethylbenzylsilane, 200 g of 35% formalin, and 60 g of zinc chloride at 80-85° for 30 hr. We obtained 52 g (44%) of chloromethylbenzyltriethylsilane.

B.p. 139-141° (3 mm), d_4^{20} 0.9910, n_D^{20} 1.5250, MR_D 78.80; calc. 77.88.

Experiment 2b. Hydrogen chloride was passed through a mixture of 76 g of triethylbenzylsilane, 40 g of paraformaldehyde, 30 g of zinc chloride, and 300 ml of carbon tetrachloride at 50-65° for 4 hr. We obtained 30 g (32%) of chloromethylbenzyltriethylsilane.

B.p. 138-139° (3 mm), d_4^{20} 0.9951, n_D^{20} 1.5258, MR_D 78.59; calc. 77.88.

3. Chloromethylation of tripropylbenzylsilane. A mixture of 79 g of tripropylbenzylsilane, 35 g of paraformaldehyde, 25 g of zinc chloride, and 250 ml of carbon tetrachloride was heated at 70-73° for 7 hr. We obtained 8 g (8.5%) of chloromethylbenzyltripropylsilane.

B.p. 155-157° (3 mm), d_4^{20} 0.9666, n_D^{20} 1.5158, MR_D 92.74; calc. 91.77.

4. Chloromethylation of tributylbenzylsilane. Hydrogen chloride was passed through a mixture of 60 g of tributylbenzylsilane, 30 g of paraformaldehyde, 30 g of zinc chloride, and 250 ml of glacial acetic acid at 80° for 2 hr with stirring. The cooled reaction products were extracted with ether. The extract was separated and distilled. We obtained 8 g (11.4%) of chloromethylbenzyltributylsilane.

B.p. 191-194° (4 mm), d_4^{20} 0.9570, n_D^{20} 1.5024, MR_D 104.62; calc. 105.66.

B. Oxidation of Chloromethylbenzyltrialkylsilanes

The oxidation was carried out in the following way: to a mixture of 3.5-4.5 g of chloromethylbenzyltrialkylsilane, 30 ml of 98% sulfuric acid, 90 ml of glacial acetic acid, and 90 ml of water was slowly added 100 g of chromiumtrioxide. The mixture was heated at 90-100° for 2 hr. The terephthalic acid obtained was identified as its dimethyl ester, whose melting point corresponded to literature data.

1. Oxidation of chloromethylbenzyltrimethylsilane. a) From 4.63 g of chloromethylbenzyltrimethylsilane (from experiment 1a) we obtained 2.745 g (78%) of terephthalic acid, which indicates the formation of about 96% of the para-isomer during the chloromethylation of trimethylbenzylsilane in an aqueous medium.

b) From 4.1 g of chloromethylbenzyltrimethylsilane (from experiment 2a) we obtained 1.85 g (57%) of terephthalic acid, which indicates the formation of about 70% of the para-isomer during the chloromethylation of trimethylbenzylsilane in carbon tetrachloride.

2. Oxidation of chloromethylbenzyltriethylsilane. a) From 4.446 g of chloromethylbenzyltriethylsilane (from experiment 1b) we obtained 2.115 g (75%) of terephthalic acid, which indicates the formation of about 93% of the para-isomer during the chloromethylation of triethylbenzylsilane in an aqueous medium.

b) From 4.462 g of chloromethylbenzyltriethylsilane (from experiment 2b) we obtained 1.752 g (61%) of terephthalic acid, which indicates the formation of about 75% of the para-isomer during the chloromethylation of triethylbenzylsilane in carbon tetrachloride.

3. Oxidation of chloromethylbenzyltripropylsilane. From 3.692 g of chloromethylbenzyltripropylsilane we obtained 1.734 g (80.6%) of terephthalic acid, which indicates the formation of only p-chloromethylbenzyltripropylsilane during the chloromethylation of tripropylbenzylsilane in carbon tetrachloride.

C. Preparation of Oxygen-Containing Organosilicon Compounds and Silicohydrocarbons from Chloromethyl Derivatives of Trimethyl- and Triethylbenzylsilanes

1. Hydrolysis of trimethyl- and triethyl(chloromethylbenzyl)silanes. a) A mixture of 28 g of chloromethylbenzyltrimethylsilane (from experiment 1a), 15 g of calcium carbonate, and 100 ml of water was heated at 100° and stirred for 25 hr. When the mixture had cooled, the reaction products were extracted with ether. The ether solution was separated, dried with calcium carbonate, and distilled. We obtained 16.7 g (64.2%) of trimethylsilylmethylbenzyl alcohol.

B. p. 114-116° (3 mm), d_4^{20} 0.9625, n_D^{20} 1.5180, MR_D 61.17; calc. 60.70.

Found %: OH 8.95, 9.22. Calculated %: OH 8.76.

The alcohol obtained was boiled for 1.5 hr and after cooling, distilled. We obtained 13.8 g (43%) of ditrimethylsilylmethylbenzyl ether. It had b.p. 203-205° (3 mm). After recrystallization from alcohol, the substance melted at 65°.

Found %: C 71.43, 71.44; H 9.34, 9.15; Si 15.16, 15.00. M 365, 368. $C_{22}H_{34}OSi_2$. Calculated %: C 71.29; H 9.24; Si 15.14. M 370.6.

b) A mixture of 47 g of chloromethylbenzyltriethylsilane (from experiment 2b), 40 g of calcium carbonate, and 200 ml of water was heated at 100° and stirred for 30 hr. Fractionation yielded 11 g (25.3%) of ditriethylsilylmethylbenzyl ether.

B.p. 235-237° (2 mm), d_4^{20} 0.9633, n_D^{20} 1.5305, MR_D 145.94; calc. 145.00. Solidification point −69.5°.

Found %: C 74.09, 73.98; H 10.21, 10.35; Si 11.54, 11.78. M 447, 445. $C_{28}H_{46}OSi_2$. Calculated %: C 73.95; H 10.20; Si 12.34. M 454.7.

2. Reduction of trimethyl- and triethyl(chloromethylbenzyl)silanes. a) To the organomagnesium compound from 30 g of magnesium and 50 g of chlorobenzyltrimethylsilane (from experiment 1a) was slowly added 80 ml of methanol and then 300 ml of 10% hydrochloric acid. The organic layer was separated, dried with calcium chloride, and fractionated. We obtained 20 g (48%) of methylbenzyltrimethylsilane.

B.p. 80.5-81° (8 mm), d_4^{20} 0.8685, n_D^{20} 1.4960, MR_D 59.97; calc. 59.15.

Found %: C 74.38, 74.36; H 10.27, 10.17; Si 15.11, 15.04. $C_{11}H_{18}Si$. Calculated %: C 74.10; H 10.17; Si 15.73.

Raman spectrum ($\Delta \nu$ in cm^{-1}): 183 (2 broad), 232 (3 broad), 333 (5), 468 (4), 599 (9 broad), 640 (3 sharp), 667 (2 broad), 695 (3 broad), 713 (1), 746 (4), 780 (1), 810 (3), 832 (5 broad), 860 (0 broad), 1000 (1), 1042 (2 sharp), 1129 (0), 1157 (6 broad), 1184 (3), 1205 (10), 1220 (1 broad), 1253 (0 broad), 1284 (1 broad), 1320 (2 broad), 1381 (3 sharp), 1411 (2 broad), 1436 (1 broad), 1574 (0), 1606 (2), 1616 (10), 2865 (1 broad), 2892 (8 broad), 2917 (3), 2955 (8 broad), 3005 (1), 3023 (1), 3048 (1).

We also isolated 12 g (28.8%) of di(trimethylsilylmethyl)bibenzyl.

B.p. 179-180° (2 mm) M.p. 68° (from alcohol).

Found %: C 74.68, 74.69; H 9.67, 9.88; Si 14.89, 14.95. M 347, 350. $C_{22}H_{34}Si_2$. Calculated %: C 74.51; H 9.66; Si 15.83. M 354.6.

b) Under the same conditions, from 35 g of chloromethylbenzyltriethylsilane (from experiment 2b) we obtained 14 g (46.4%) of methylbenzyltriethylsilane.

B.p. 102° (2 mm), d_4^{20} 0.8968, n_D^{20} 1.5055, MR_D 73.51; calc. 72.68.

Found %: C 76.52, 76.52; H 10.87, 10.88; Si 12.56. $C_{14}H_{24}Si$. Calculated %: C 76.30; H 10.97; Si 12.73.

Raman spectrum ($\Delta \nu$ in cm^{-1}): 305 (3 broad), 388 (0), 468 (3), 563 (6), 585 (1 broad), 643 (2 broad), 738 (0), 759 (3 broad), 813 (2), 834 (5), 972 (1 broad), 1008 (1 broad), 1044 (0), 1158 (4 broad), 1183 (2 sharp), 1205 (10), 1380 (2), 1417 (2), 1463 (3 broad), 1614 (10), 2875 (8 broad), 2912 (6 broad), 2955 (3 broad), 3005 (1), 3025 (1 broad).

We also isolated 10.5 g (35%) of di(triethylsilylmethyl)bibenzyl.

B.p. 233-236° (2 mm), d_4^{20} 0.9392, n_D^{20} 1.5300, MR_D 144.29; calc. 143.23.

Found %: C 76.92, 76.94; H 10.70, 10.58; Si 12.74, 12.36. $C_{28}H_{46}Si_2$. Calculated %: C 76.64; H 10.57; Si 12.79.

3. Reaction of trimethylsilylmethylbenzylmagnesium chloride with trimethylchlorosilane. To the trimethylsilylmethylbenzylmagnesium chloride from 24 g of magnesium and 101 g of chloromethylbenzyltrimethylsilane (from experiment 1a) was added 45 g of trimethylchlorosilane dropwise. The reaction mixture was heated for 10 hr. We obtained 15 g (12.7%) of di(trimethylsilylmethyl)benzene. It had m.p. 58-58.5° (from alcohol).

Found %: C 67.27, 67.32; H 10.46, 10.40; Si 21.75, 22.04. $C_{14}H_{25}Si_2$. Calculated %: C 67.14; H 10.46; Si 22.40, M 245, 248; calc. 250.5.

We also isolated 26.5 g (31.2%) of di(trimethylsilylmethyl)bibenzyl.

4. Reaction of triethylsilylmethylbenzylmagnesium chloride with triethylbromosilane. To the triethylsilylmethylbenzylmagnesium chloride from 24 g of magnesium and 128 g of chloromethylbenzyltrimethylsilane (from experiment 2b) was added 95 g of triethylbromosilane dropwise. The reaction mixture was heated for 10 hr. We obtained 40 g (23.8%) of di(triethylsilylmethyl)benzene.

B.p. 170-172° (2 mm), d_4^{20} 0.8960, n_D^{20} 1.5050, MR_D 110.77; calc. 109.73.

Found %: C 72.03, 72.02; H 11.48, 11.44; Si 16.43, 16.22. M 327, 329. $C_{20}H_{38}Si_2$. Calculated %: C 71.78; H 11.45; Si 16.77. M 334.6.

We also isolated 50 g (44.5%) of di(triethylsilylmethyl)bibenzyl.

SUMMARY

1. The chloromethylation of a series of trialkylbenzylsilanes in an aqueous medium and in carbon tetrachloride was studied. The chloromethylation of trialkylbenzylsilanes became more difficult with an increase in the size of their alkyl radicals. It was shown that the chloromethylation of trialkylbenzylsilanes under different conditions leads to different contents of the para- and ortho-isomers in the chloromethyl derivatives.

2. A series of oxygen-containing organosilicon compounds and silicohydrocarbons were prepared from the chloromethylbenzyltrialkylsilanes.

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FORMATION OF TRIETHYLSILOXYBOROSILOXANES

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Attempts have been made to prepare organosilicon compounds containing boron by various methods. Attempts to use the reaction of boron trihalides with alkoxy derivatives of silanes [1] and with hydroxysilanes [2] did not give positive results as the reactions proceeded according to the following scheme:

$$BX_3 + -\overset{|}{\underset{|}{Si}}-OR \rightarrow -\overset{|}{\underset{|}{Si}}-X + \overset{X}{\underset{OR}{\overset{|}{B}}}-X$$
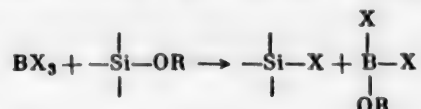
R = alkyl or H; X = halogen (Cl or Br).

The action of sodium silanolates on alkylboron halides yielded boron-containing organosilicon compounds [2].

$$R_{3-n}BX_n + nNaOSiR_3 \rightarrow R_{3-n}B(OSiR_3)_n + nNaX$$

The reaction of trialkylalkoxysilanes and trialkylchlorosilanes with boric acid formed tris(trialkylsilyl)borates according to the scheme [3]:

$$3R_3SiOR' + B(OH)_3 \rightarrow [R_3SiO]_3B + 3R'OH.$$

R = alkyl or Cl

The reaction of boric esters with trialkylsilanols in the presence of their sodium derivatives also yielded tris(trialkylsilyl)borates [3].

$$B(OR)_3 + 3R_3'SiOH \xrightarrow{R_3SiONa} 3ROH + (R_3'SiO)_3B$$
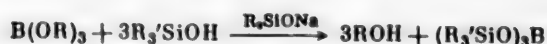
At a temperature above 300° and under pressure, tris(trialkylsilyl)borates were formed from hexaalkyldisiloxanes and boric anhydride [3].

$$3R_3SiOSiR_3 + B_2O_3 \rightarrow 2B(OSiR_3)_3$$

We studied the reaction of triethylhydroxysilane with ethyl borate with the aim of preparing triethylsiloxydiethoxyboron. Experiments showed that even when the reaction of ethyl borate with triethylhydroxysilane was carried out with a molar ratio, tris(triethylsiloxy)boron was formed; triethylsiloxydiethoxyboron could not be isolated. It is probable that triethylsiloxydiethoxyboron disproportionated during distillation to form a more stable compound, namely, tris(triethylsiloxy)boron.

In subsequent experiments, ethyl borate was first condensed with triethylhydroxysilane with distillation of the ethanol formed during the reaction.

$$2(C_2H_5)_3SiOH + B(OC_2H_5)_3 \rightarrow [(C_2H_5)_3SiO]_2B(OC_2H_5) + 2C_2H_5OH$$

$$(1)$$

Diethyldiacetoxysilane was then added and the reaction mixture again heated for distillation of the ethyl acetate.

$$2[(C_2H_5)_3SiO]_2B(OC_2H_5) + (C_2H_5)_2Si(OCOCH_3)_2 \rightarrow 2C_2H_5OCOCH_3 +$$

$$\begin{array}{c} (C_2H_5)_2 \\ | \\ + (C_2H_5)_3SiO-B-O-Si-O-B-OSi(C_2H_5)_3 \\ | \qquad\qquad\qquad | \\ (C_2H_5)_3SiO \qquad\qquad OSi(C_2H_5)_3 \end{array}$$

(2)
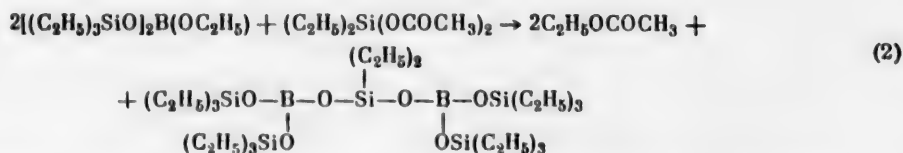
Two vacuum distillations yielded 1,5-bis(triethylsiloxyboro)-3-diethyldiborosiloxane in 24.7% yield.

1,5-Bis(triethylsiloxyboro)-3-dimethyldiborosiloxane was readily obtained by reaction (2) by the use of dimethyldiacetoxysilane instead of diethyldiacetoxysilane. The action of diethylsilanediol on the condensation product of triethylhydroxysilane and ethyl borate also yielded readily 1,5-bis(triethylsiloxyboro)-3-diethyldiborosiloxane.

$$2[(C_2H_5)_3SiO]_2B(OC_2H_5) + (C_2H_5)_2Si(OH)_2 \rightarrow 2C_2H_5OH +$$

$$\begin{array}{c} (C_2H_5)_2 \\ | \\ + (C_2H_5)_3SiOB-O-Si-O-B-OSi(C_2H_5)_3 \\ | \qquad\qquad\qquad | \\ (C_2H_5)_3SiO \qquad\qquad OSi(C_2H_5)_3 \end{array}$$
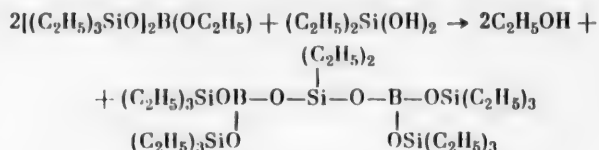
EXPERIMENTAL

Reaction of ethyl borate with triethylhydroxysilane. A mixture of 27.19 g of triethylhydroxysilane and 30 g of ethyl borate was heated at 150-200° in a Favorskii flask. The alcohol liberated (9.9 g) was distilled from the mixture during heating. The residue was vacuum distilled to yield the following fractions: 1st, 30-45° (2 mm), 2.7 g; 2nd, 45-145° (2 mm), 11.4 g; 3rd, 145-146° (2 mm), 13.9 g. It was not possible to isolate pure products by redistillation of the light fractions. The 3rd fraction had properties identical with those of tris(triethylsiloxy)boron, which was described previously (n_D^{20} 1.4378, d_4^{20} 0.8903). Literature data for tris(triethylsiloxy)boron [3]: n_D^{20} 1.4379, d_4^{20} 0.8918. The yield of tris(triethylsiloxy)boron was 52%.

Condensation of triethylhydroxysilane with ethyl borate and diethyldiacetoxysilane. To the product remaining after distillation of the alcohol from a reaction mixture consisting of 29.16 g of ethyl borate and 26.4 g of triethylhydroxysilane was added 40.86 g of diethyldiacetoxysilane. After the distillation of 28.9 g of ethyl acetate, the residue was vacuum distilled; we collected the following fractions: 1st, 130-158° (10 mm), 9.3 g; 2nd, 170-175° (10 mm), 17.8 g; 3rd, 177-200° (10 mm), 12 g. Redistillation of the 2nd fraction yielded 8.2 g of a substance with b.p. 176-179° (12 mm) and n_D^{20} 1.4390, which was 1,5-bis(triethylsiloxyboro)-3-diethyldiborosiloxane. The yield was 24.7%.

Found %: C 49.66, 49.42; H 10.50, 10.50; B 2.92, 3.14; Si 21.9, 21.46. $C_{28}H_{70}O_6Si_5B_2$. Calculated %: C 50.57; H 10.61; B 3.25; Si 21.11.

Condensation of triethylhydroxysilane with ethyl borate and dimethyldiacetoxysilane. The reaction, which was analogous to the previous one, but with dimethyldiacetoxysilane, was carried out with 29.16 g of ethyl borate and 26.4 g of triethylhydroxysilane; 9.8 g of alcohol distilled. Then 35.2 g of dimethyldiacetoxysilane was added and the reaction mixture again heated for the distillation of ethyl acetate (29.6 g). Distillation in vacuum yielded the following fractions: 1st, 40-110° (8 mm), 13.2 g; 2nd, 150-180° (10 mm) 2.9 g; 3rd, 180-185° (10 mm), 17.8 g. Individual products could not be isolated by redistillation of the 1st and 2nd fractions. Redistillation of the 3rd fraction yielded 6.75 g of a product with b.p. 169-175° (8 mm) and n_D^{20} 1.4320, which was 1,5-bis(triethylsiloxyboro)-3-dimethyldiborosiloxane. The yield was 21.2%.

Found %: C 49.45, 49.35; H 10.24, 10.30; B 3.38, 3.24; Si 21.46, 21.52. $C_{26}H_{66}O_6Si_5B_2$. Calculated %: C 49.05; H 10.37; B 3.56; Si 21.99.

Condensation of triethylhydroxysilane with ethyl borate and diethylsilanediol. Into a Favorskii flask were placed 21.48 g of ethyl borate and 19.45 g of triethylhydroxysilane and 9.1 g of alcohol was distilled by heating. After the addition of 17.72 g of diethylsilanediol, the mixture was heated for the distillation of alcohol (8.7 g); vacuum distillation of the residue yielded 7.2 g of material distilling at 45-110° (8 mm). Distillation of the residue yielded the

following fractions: 1st, 140-164° (8 mm), 2.40 g; 2nd, 164-192° (8 mm), 14.4 g; 3rd, 192-198° (8 mm), 7.9 g. Redistillation of the 2nd and 3rd fractions yielded 7.10 g of a product with b.p. 170-175° (8 mm), and n_D^{20} 1.4384, which was 1,5-bis(triethylsiloxyboro)-3-diethyldiborosiloxane. The yield was 24.5%.

Found %: C 50.39, 50.29; H 10.52, 10.52; B 3.32, 3.30; Si 20.98, 21.34. $C_{29}H_{70}O_6Si_6B_2$. Calculated %: C 50.57; H 10.61; B 3.25; Si 21.11.

SUMMARY

1. Condensation of ethyl borate with triethylhydroxysilane and diethyldiacetoxysilane yielded 1,5-bis(triethylsiloxyboro)-3-diethyldiborosiloxane.

2. Condensation of ethyl borate with triethylhydroxysilane and dimethyldiacetoxysilane yielded 1,5-bis(triethylsiloxyboro)-3-dimethyldiborosiloxane.

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ESTERS OF PHOSPHORUS ACIDS WITH DIFFERENT RADICALS

II. SYNTHESIS OF DIALKYL CHLOROPHOSPHATES AND TRIALKYL PHOSPHATES WITH DIFFERENT RADICALS

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Dialkyl chlorophosphates form a class of organophosphorus compounds that has been studied thoroughly [1-4]. However, dialkyl chlorophosphates with different radicals have been studied little and only two methods of preparing them are known: the reaction of alkyl and aryl dichlorophosphates with alcohols or alcoholates [5-7] and chlorination of the methyl ethylene ester of phosphorous acid [8].

We developed a general method for the preparation of mixed dialkyl chlorophosphates by the chlorination of dialkyl phosphites with different radicals.
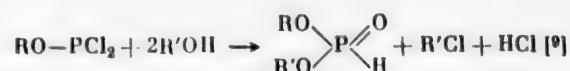
Redistilled dialkyl phosphites with different radicals were chlorinated by one of two known methods.
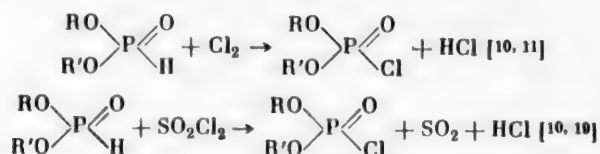
The careful removal of hydrogen chloride in vacuum is required in chlorination both with chlorine and with sulfuryl chloride. Four dialkyl chlorophosphates with different radicals were synthesized (see table for properties). The dialkyl chlorophosphates were colorless, mobile liquids with a sharp smell, which dissolved readily in organic solvents; they were hydrolyzed by water.

The dialkyl chlorophosphates obtained were used for the synthesis of trialkyl phosphates [(RO)(R'O)(R"O)PO] with different radicals, which find very wide application in industry and agriculture [12-15].

Three methods of preparing mixed trialkyl(aryl)phosphates have been described in the literature (mainly in the patent literature): 1) the reaction of phosphorus oxychloride with alcohols or their sodium derivatives with successive replacement of the chlorine atoms by radicals from aliphatic alcohols or phenol derivatives [12-14, 16, 17]; 2) by the reaction of an ester of glycolphosphorous acid with chloral [15], and 3) by the reaction of trialkyl phosphites with chloro- or dichloroacetone [18].

We developed a general method for the preparation of trialkyl(aryl)phosphates with different radicals from mixed dialkyl phosphites [9] and the dialkyl chlorophosphates with different radicals described above, according to the scheme:
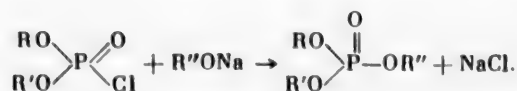
Formula	Boiling point (pressure in mm)	d_4^{20}	n_D^{20}	Yield (%)
$(C_2H_5O)(C_4H_9O)P(O)Cl$	86—87° (1)	1.1370	1.4206	87
$(iso\text{-}C_5H_{11}O)(C_6H_{13}O)P(O)Cl$	122—125 (0.2)	1.0450	1.4397	87.5
$(iso\text{-}C_5H_{11}O)(C_7H_{15}O)P(O)Cl$	129—132 (0.3)	1.0560	1.4500	90
$(iso\text{-}C_5H_{11}O)(C_8H_{17}O)P(O)Cl$	132—134 (0.3)	1.0350	1.4550	88.5
$(C_4H_9O)(iso\text{-}C_5H_{11}O)(C_6H_{13}O)PO$	126—127 (0.2)	0.9596	1.4295	86.7
$(C_4H_9O)(iso\text{-}C_5H_{11}O)(C_7H_{15}O)PO$	129—131 (0.2)	0.9551	1.4291	85
$(C_4H_9O)(iso\text{-}C_5H_{11}O)(C_8H_{17}O)PO$	131—132 (0.1)	0.9527	1.4310	80.5

Three mixed trialkyl phosphates were synthesized by this method (see table for properties). They were all colorless oily liquids with a weak odor, dissolved readily in organic solvents and were insoluble in water.

EXPERIMENTAL

1. Ethyl butyl chlorophosphate. Into a Claisen flask was placed 83 g of ethyl butyl phosphite and with the continuous bubbling of dry air, 81 g of sulfuryl chloride was added from a dropping funnel at such a rate that the temperature of the reaction mixture did not rise above 35-40°. Bubbling was continued for a further hour in a water-pump vacuum until the pressure reached 10-15 mm. The product distilled at 86-87° (1 mm). The yield was 87.2 g (87%).

d_4^{20} 1.137, n_D^{20} 1.4206, MR_D 44.70; calc. 45.12.

Found %: P 14.88, 15.0; Cl 17.20, 17.35. $C_6H_{14}O_3PCl$. Calculated %: P 15.05; Cl 17.24.

2. Isoamyl hexyl chlorophosphate. Into a Claisen flask was placed 80 g of isoamyl hexyl phosphate. With external cooling to 0-5°, dried chlorine was passed in through a capillary until a green color appeared. The hydrogen chloride and excess chlorine were removed under reduced pressure in a stream of dry air over a period of 2 hr and the residue distilled. We obtained 80 g (87.5%) of isoamyl hexyl chlorophosphate.

B.p. 122-125° (0.2 mm), d_4^{20} 1.0452, n_D^{20} 1.4397, MR_D 68.21; calc. 68.21.

Found %: P 11.23, 11.40; Cl 13.07, 13.20. $C_{11}H_{24}O_3PCl$. Calculated %: P 11.44; Cl 13.10.

3. Isoamyl heptyl chlorophosphate. Under the conditions described in experiment 2, from 100.7 g of isoamyl heptyl phosphite we obtained 102.5 g (90%) of isoamyl heptyl chlorophosphate.

B.p. 129-132° (0.3 mm), d_4^{20} 1.056, n_D^{20} 1.4500, MR_D 72.44; calc. 72.83.

Found %: P 10.85, 10.89; Cl 12.47, 12.40. $C_{12}H_{26}O_3PCl$. Calculated %: P 10.88; Cl 12.45.

4. Isoamyl octyl chlorophosphate. Under the conditions described in experiment 2, from 132.3 g of isoamyl octyl phosphite we obtained 147 g (88.5%) of isoamyl octyl chlorophosphate.

B.p. 132-134° (0.3 mm), d_4^{20} 1.035, n_D^{20} 1.455, MR_D 78.32; calc. 77.45.

Found %: P 10.27, 10.32; Cl 11.48, 11.58. $C_{13}H_{28}O_3PCl$. Calculated %: P 10.37; Cl 11.53.

5. Butyl isoamyl hexyl phosphate. Into a four-necked flask with a stirrer, thermometer, dropping funnel, and reflux condenser was placed 27 g of sodium butylate in 150 ml of xylene; 50 g of isoamyl hexyl chlorophosphate in 50 ml of xylene was added from the dropping funnel at 45° with vigorous stirring. When the chlorophosphate had been added, stirring was continued for a further 1.5 hr. The mixture was cooled to room temperature and filtered; the filtrate was made alkaline to phenolphthalein with 5% alkali solution, washed with water (2 · 50 ml) and dried with baked potassium carbonate. The solvent was removed and the product vacuum-distilled. Two distillations yielded 50 g (86.7%) of butyl isoamyl hexyl phosphate.

B.p. 126-127° (0.2 mm), d_4^{20} 0.9596, n_D^{20} 1.4295, MR_D 83.11; calc. 83.46.

Found %: P 10.08, 10.14; C 57.97, 58.27; H 10.73, 10.68. $C_{15}H_{33}O_4P$. Calculated %: P 10.04; C 58.41; H 10.78.

6. Butyl isoamyl heptyl phosphate. Under the condition described in experiment 5, to 54 g of sodium butylate was added 99.67 g of isoamyl heptyl chlorophosphate. We obtained 96 g (85%) of butyl isoamyl heptyl phosphate.

B.p. 129-131° (0.2 mm), d_4^{20} 0.9551, n_D^{20} 1.4291, MR_D 87.93; calc. 88.08.

Found %: P 10.0, 9.70; C 58.98, 59.45; H 10.89, 10.95. $C_{16}H_{35}O_4P$. Calculated %: P 9.61; C 59.60; H 10.94.

7. Butyl isoamyl octyl phosphate. Under the conditions described in experiment 5, to 54 g of sodium butylate was added 104.5 g of isoamyl octyl chlorophosphate. We obtained 95 g (80.5%) of butyl isoamyl octyl phosphate.

B.p. 131-132° (0.1 mm), d_4^{20} 0.9527, n_D^{20} 1.4310, MR_D 92.0; calc. 92.39.

Found %: P 8.98, 9.18. $C_{17}H_{37}O_4P$. Calculated %: P 9.21.

SUMMARY

1. A general method was developed for the preparation of dialkyl chlorophosphates with different radicals in yields of 87-90%.

2. A method was developed for the preparation of trialkyl phosphates with different radicals in yields of 80-88.5%.

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SYNTHESIS OF SOME DERIVATIVES OF PHENYL TRIFLUOROMETHYL SULFIDE AND PHENYL TRIFLUOROMETHYL SULFONE

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Continuing the study of aromatic compounds with fluorine-containing substituents, we synthesized a series of acetyl-, carboxyl- and fluoro-derivatives of phenyl trifluoromethyl sulfide and phenyl trifluoromethyl sulfone.

p-Trifluoromethylmercapto- and p-trifluoromethylsulfonylacetophenones were obtained from the acid chlorides of the corresponding carboxylic acids and ethoxymagnesiummalonic ester.
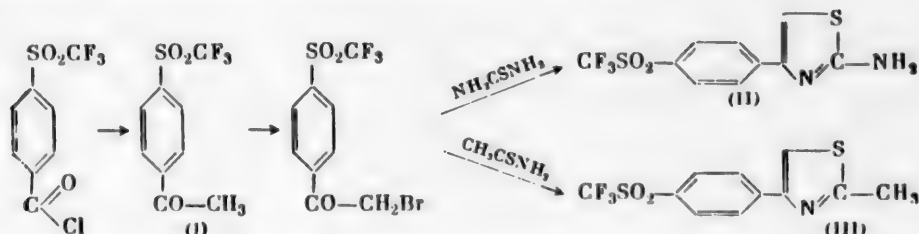
The ketone (I) was converted to the bromo ketone and then to the thiazole derivatives (II) and (III). From the base (III) we prepared a quaternary salt and from the latter, two dyes, namely, the symmetrical thiazolocarbocyanine (IV) and the merocyanine (V), whose formulas and absorption maxima in alcohol are given below. The absorption maximum of the dye without the trifluoromethylsulfonyl group is given in brackets.
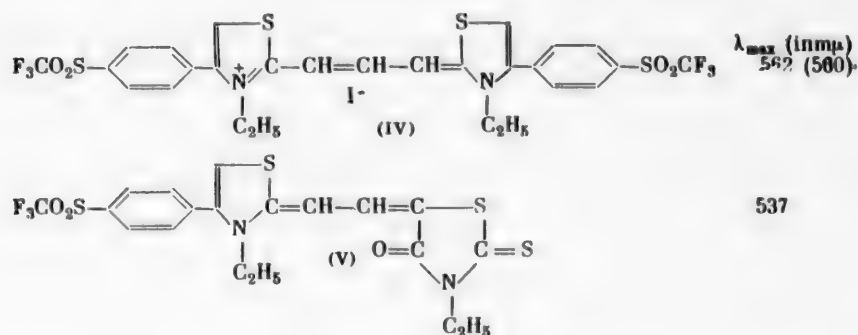
The introduction of the CF_3SO_2 group into the molecule of the 4,4'-diarylthiazolocarbocyanine hardly affected the absorption of the dye. On other examples, E. D. Sych explained this fact by steric hindrance forcing the aryl groups out of the plane of the thiazole ring and thus disrupting their conjugation with the dye chromophore [1].

o-Fluorophenyl trifluoromethyl sulfides and sulfones were obtained by scheme (1), the para-derivatives by scheme (2), and the meta-derivatives analogously from m-aminophenyl trifluoromethyl sulfide.

1.

SCH₃ / NH₂ → SCH₃ / F → SCCl₃ / F → SCF₃ / F → SO₂CF₃ / F

SCH₃ / NH₂ → SCF₃ / F → SO₂CF₃ / F
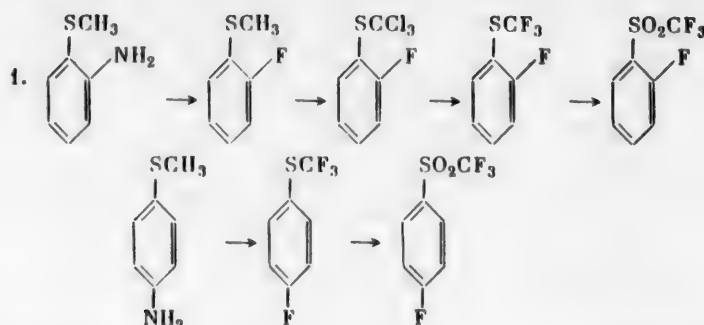
By replacing the chlorine atom by fluorine by the method of N. N. Vorozhtsev and G. G. Yakobson [2], we prepared 3-nitro-4-fluorophenyl trifluoromethyl sulfone, which contains an extremely labile fluorine atom.

SO₂CF₃ ... NO₂ / Cl —KF→ SO₂CF₃ ... NO₂ / F
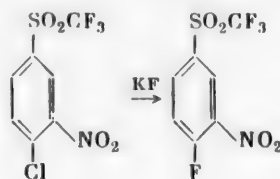
By replacement of the amino group in m-aminophenyl trifluoromethyl sulfide by a cyano group by Sandmeyer's method and by hydrolysis by boiling with sodium hydroxide solution, we synthesized the corresponding carboxylic acid. Oxidation of the latter yielded m-trifluoromethylsulfonylbenzoic acid.

SCF₃ / NH₂ → SCF₃ / CN → SCF₃ / COOH → SO₂CF₃ / COOH
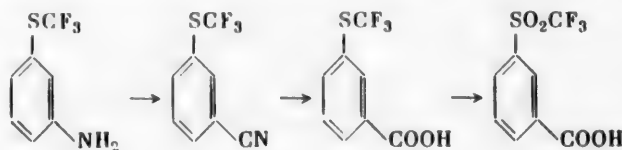
EXPERIMENTAL

Amide of p-trifluoromethylsulfonylbenzoic acid. A solution of 10 g of the corresponding nitrile [3] in 30 ml of concentrated sulfuric acid was left overnight. The mixture was poured into water and the precipitate collected and dried. The yield was 11 g (quantitative) and the m.p. 190-192°. After recrystallization from alcohol, the substance had m.p. 194-195° [3].

p-Trifluoromethylsulfonylbenzoic acid. To a solution of 7.6 g of the amide in 30 ml of concentrated sulfuric acid at 0 to +5° was added 8 g of dry, ground sodium nitrite in portions with stirring and then the temperature was allowed to rise to room temperature over a period of 30 min and finally kept at 60° for a further 30 min. At the latter temperature, 3 ml of water was added and the mixture stirred for 1 hr. It was then diluted with water. The precipitated acid was dissolved in 10% sodium carbonate solution, the solution filtered to remove unreacted amide, and the acid precipitated with 20% hydrochloric acid. The yield was 6.8 g (90%) and the m.p. 242-243° [3].

p-Trifluoromethylsulfonylbenzoyl chloride had b.p. 120-121° at 6-7 mm and m.p. 31-31.5° [3].

p-Trifluoromethylsulfonylacetophenone. The preparation of this product was analogous to the preparation of o-nitroacetophenone from o-nitrobenzoyl chloride [4]. The yield was 70%, the b.p. 157° at 12 mm, and the m.p. 56-57°.

Found %: S 12.70, 12.52. $C_9H_7O_3SF_3$. Calculated %: S 12.70.

p-Trifluoromethylsulfonylphenacyl bromide. To a solution of 3 g of p-trifluoromethylsulfonylacetophenone in 12 ml of glacial acetic acid at room temperature was added a solution of 1.87 g of bromine in 6 ml of glacial acetic

acid dropwise and then the mixture stirred for 30 min and poured onto ice. The yield was 3.73 g (95%) and the m.p. 46-47° (from aqueous alcohol).

Found %: Br 24.36; 24.50. $C_9H_6O_3SF_3Br$. Calculated %: Br 24.20.

Bromination at 65-70° formed a considerable amount of ω,ω-dibromo-p-trifluoromethylsulfonylacetophenone. It had m.p. 142-142.5°.

Found %: Br 39.42, 39.31. $C_9H_5O_3SF_3Br_2$. Calculated %: Br 39.0.

2-Amino-4-(p-trifluoromethylsulfonylphenyl)-thiazole. A mixture of 1.5 g of p-trifluoromethylsulfonyl-phenacyl bromide, 0.36 g of thiourea, and 5 ml of anhydrous alcohol was boiled for 1 hr. The alcohol was removed, the residue ground in a mortar with 20 ml of aqueous ammonia, and the product collected. The yield was 1.0 g (71.6%) and the m.p. 194-195° (from aqueous alcohol).

Found %: N 9.31, 9.29; S 20.01, 20.04. $C_{10}H_7O_2N_2S_2F_3$. Calculated %: N 9.1; S 20.79.

2-Methyl-4-(p-trifluoromethylsulfonylphenyl)-thiazole. A mixture of 1.5 g of p-trifluoromethylsulfonyl-phenacyl bromide, 0.34 g of thioacetamide, and 6 ml of anhydrous alcohol was boiled for 30 min. The mixture was diluted with a 5-fold amount of water, cooled, and made alkaline with ammonia. Recrystallization from alcohol yielded 0.8 g (57.5%) of product with m.p. 99-100°.

Found %: N 4.54, 4.44. $C_{11}H_8O_2NS_2F_3$. Calculated %: N 4.56.

Iodoethylate of 2-methyl-4-(p-trifluoromethylsulfonylphenyl)-thiazole. A mixture of 1.1 g of the base and 0.7 g of diethyl sulfate was heated at 140-150° for 4.5 hr. The product was washed with ether and mixed with a saturated aqueous solution of potassium iodide. The yield was 0.9 g (56.0%).

3,3'-Diethyl-4,4'-di-(p-trifluoromethylsulfonylphenyl)-thiazolocarbocyanine iodide. A mixture of 0.5 g of the iodoethylate of 2-methyl-4-(p-trifluoromethylsulfonylphenyl)-thiazole, 0.5 ml of orthoformic ester, and 0.5 ml of pyridine was heated at 120° for 2 hr. The product was recrystallized from alcohol. The yield was 0.2 g (47.2%) and the decomp. p. 239-241°.

Found %: I 15.34, 15.45. $C_{27}H_{23}O_4N_2S_4F_6I$. Calculated %: I 15.71.

3-Ethyl-5[3'-ethyl-4'-(p-trifluoromethylsulfonylphenyl)-thiazolinylidene-2'-ethylidene]-thiazolidenethion-2-one-4. A mixture of 0.4 g of the iodoethylate of 2-methyl-4-(p-trifluoromethylsulfonylphenyl)-thiazole, 0.24 g of 3-ethyl-5-acetanilidomethylenerhodanine, 0.1 g of triethylamine, and 5 ml of anhydrous alcohol was boiled for 45 min. The product was recrystallized from aqueous acetic acid. The yield was 0.18 g (40.9%) and the m.p. 222°.

Found %: N 5.54, 5.57. $C_{19}H_{17}O_3N_2S_4F_3$. Calculated %: N 5.54.

p-Trifluromethylmercaptobenzoyl chloride [3] was obtained from p-trifluoromethylmercaptobenzoic acid [5] and thionyl chloride.

p-Trifluoromethylmercaptoacetophenone. Into a three-necked flask, fitted with a dropping funnel, stirrer, and reflux condenser, were placed 2.08 g of magnesium, 2 ml of anhydrous alcohol, and 6 drops of dry carbon tetrachloride. The mixture was heated and stirred while 60 ml of absolute ether was added followed by a solution of 13.6 g of freshly distilled malonic ester in 8 ml of anhydrous alcohol and 10 ml of absolute ether. The mixture was boiled for 3 hr. Then 19.4 g of p-trifluoromethylmercaptobenzoyl chloride in 20 ml of ether was added. Boiling and stirring were continued until the mixture thickened. Then 80 ml of 20% sulfuric acid was added to dissolve the precipitate. The ether layer was separated and the aqueous layer extracted with ether. The ether was removed and to the residue were added 25 ml of glacial acetic acid, 3 ml of concentrated sulfuric acid, and 15 ml of water. The mixture was stirred and boiled for 10 hr (until the evolution of carbon dioxide ceased), made alkaline with 20% sodium hydroxide solution, and extracted with ether. The ether was removed and the product distilled. The yield was 13.35 g (76%). The product had b.p. 115-117° at 20 mm and m.p. 21.5° (corr.).

Found %: S 14.17, 14.32. $C_9H_7OSF_3$. Calculated %: S 14.55.

p-Trifluoromethylmercaptophenacyl bromide. To a solution of 13.3 g of p-trifluoromethylmercaptoacetophe-none in 80 ml of dry chloroform at 20° was added 9.45 g of bromine in 20 ml of chloroform over a period of 15 min. The mixture was stirred for 45 min. The chloroform layer was washed with water and dried and the chloroform removed. The yield was 17.55 g (98.5%) and the m.p. 55-56°. After recrystallization from methanol, the product had m.p. 57-58°.

Found %: Br 26.25, 26.10; F 20.30, 20.40. $C_9H_6OSF_3Br$. Calculated %: Br 26.79; F 20.43.

3-Nitro-4-flurophenyl trifluoromethyl sulfone. A mixture of 5.5 g of 3-nitro-4-chlorophenyl trifluoromethyl sulfone and 1.45 g of dry, finely ground potassium fluoride was stirred at 180-200° for 7 hr. The mixture was cooled and the product extracted with hot benzene. The benzene was removed and the product distilled. The yield was 3.7 g (71.3%) and the product had b.p. 110-111° at 1 mm and n_D^{17} 1.4915.

Analysis of the residual mixture of KCl and KF for chlorine showed that the replacement of chlorine by fluorine was quantitative. Reduction of this product gave an amine with m.p. 65-66° in 93% yield [6].

o-Fluorophenyl methyl sulfide. A 17 g sample of o-aminophenyl methyl sulfide was dissolved in 60 ml of 20% hydrochloric acid and diazotized at 0° with 8.6 g of sodium nitrite in 25 ml of water. The diazo solution was filtered and cooled to 0° and a cold solution of 20 g of $NaBF_4$ added. The diazonium fluoborate was collected, washed with 10 ml of iced water, pressed out carefully, and washed with dry ether. It was dried in a vacuum desiccator over P_2O_5. The yield was 20.9 g (71.9%). The diazonium fluoborate was decomposed in two portions and the product steam distilled and extracted with ether. The yield was 3.2 g (25.8%) and the b.p. 193-194°.

Found %: S 22.12, 22.26. C_7H_7SF. Calculated %: S 22.52.

o-Fluorophenyl trifluoromethyl sulfide. A solution of 3.2 g of o-fluorophenyl methyl sulfide in 8 ml of dry chloroform was placed in an ice bath and chlorinated with a stream of dry chlorine with irradiation with a 200 w lamp until chlorine vapor appeared. Chlorine was then passed for a further 15 min and the chloroform removed in vacuum. The yield of o-fluorophenyl trichloromethyl sulfide was quantitative. The product was mixed with 6 g of anhydrous antimony trifluoride. The mixture was heated with a burner and a fraction boiling at 140-170° distilled. The product was extracted with ether and the ether solution washed free from antimony salts with 20% hydrochloric acid. The yield was 1.8 g (40.7%). The product had b.p. 145-146°, n_D^{20} 1.4550, d_{20}^{20} 1.170.

Found %: S 16.04, 16.14. $C_7H_4SF_4$. Calculated %: S 16.32.

o-Fluorophenyl trifluoromethyl sulfone. To a solution of 5 g of chromium trioxide in 10 ml of glacial acetic acid at room temperature was added 1.8 g of o-fluorophenyl trifluoromethyl sulfide dropwise with stirring. The mixture evolved heat. It was boiled and stirred for 4 hr and poured into water and the sulfone obtained steam distilled. The product was extracted from the distillate with ether and the ether layer washed with sodium carbonate solution and water. The ether was removed and the product distilled. The yield was 1.2 g (57%). The product had b.p. 208-209°, n_D^{20} 1.4565, d_{20}^{20} 1.503.

Found %: S 13.78, 14.09. $C_7H_4O_2SF_4$. Calculated %: S 14.03.

m-Fluorophenyl trifluoromethyl sulfide. A solution of 15.4 g of m-aminophenyl trifluoromethyl sulfide [7] in 60 ml of 20% hydrochloric acid was cooled to 0°, 50 g of ice added, and the amine diazotized with 8.1 g of sodium nitrite in 40 ml of water at 0-5°. The diazonium salt solution was filtered and to it was added a solution of fluoboric acid obtained from 25 ml of 40% hydrofluoric acid and 7.5 g of boric acid. The mixture was cooled to 0° and the diazonium fluoborate collected. It was washed with 10 ml of iced water, pressed out, and washed with ether. The product was dried in a vacuum desiccator over P_2O_5. The yield of the diazonium fluoborate was 18 g (87.6%). The diazonium fluoborate was decomposed and the product steam distilled and extracted with ether. The ether was removed and the product distilled. The yield was 8.2 g (61.5%). The product had b.p. 137°, n_D^{20} 1.4497, d_{20}^{21} 1.343.

Found %: S 16.02, 16.40. $C_7H_4SF_4$. Calculated %: S 16.32.

m-Fluorophenyl trifluoromethyl sulfone was obtained analogously to the ortho-derivative. The yield was 4.0 g (71.5%). The product had b.p. 195-195.5°, n_D^{20} 1.4500, d_{20}^{20} 1.484.

Found %: S 14.13, 14.33. $C_7H_4O_2SF_4$. Calculated %: S 14.03.

p-Fluorophenyl trifluoromethyl sulfide was obtained analogously to the meta-derivative. The yield of the diazonium fluoborate was 65%. The yield of p-fluorophenyl trifluoromethyl sulfide was 45%. The product had b.p. 138°, n_D^{18} 1.4490, d_{20}^{18} 1.355.

Found %: S 16.42, 16.49. $C_7H_4SF_4$. Calculated %: S 16.32.

p-Fluorophenyl trifluoromethyl sulfone was obtained analogously to the ortho-derivative. The yield was 75%. The product had b.p. 196-197°, n_D^{20} 1.4530, d_{20}^{20} 1.503.

Found %: S 13.78, 13.92. $C_7H_4O_2SF_4$. Calculated %: S 14.03.

m-Trifluoromethylmercaptobenzonitrile. To a solution of 12.85 g of m-trifluoromethylmercaptoaniline [7] in 20 ml of hydrochloric acid (d 1.19) was added 100 g of ice and the amine diazotized with 4.8 g of sodium nitrite in 20 ml of water at 0-5°. The solution was filtered and neutralized to Congo with sodium acetate. The diazo solution was added with stirring at 5-7° over a period of 20 min to a solution of 27 g of sodium cyanide and 10 g of cuprous chloride in 45 ml of water. On the following day the mixture was heated to 45°. The nitrile was steam distilled and extracted with ether. The product was vacuum distilled. It had b.p. 105-106° at 25 mm and the yield was 6.07 g (45%).

Found %: N 6.65, 6.81. $C_8H_4NSF_3$. Calculated %: N 6.89.

m-Trifluoromethylmercaptobenzoic acid. A 3.58 g sample of the nitrile was boiled with 60 ml of 10% sodium hydroxide on a glycerol bath for 4 hr (until the oil disappeared). The solution was filtered and the product precipitated with 20% hydrochloric acid and collected. Recrystallization from aqueous alcohol gave 3.0 g (76.5%) of product with m.p. 75-76°.

Found %: S 14.21, 14.53. $C_8H_5O_2SF_3$. Calculated %: S 14.41.

Amide of m-trifluoromethylmercaptobenzoic acid. A 0.28 g sample of m-trifluoromethylmercaptobenzonitrile was dissolved in 1.5 ml of concentrated sulfuric acid and left at room temperature overnight. The mixture was diluted with water and the precipitate collected and washed with 5% sodium carbonate solution and then water. The yield was 0.29 g (95%) and the m.p. 122°.

Found %: N 6.08, 6.11. $C_8H_6ONSF_3$. Calculated %: N 6.34.

m-Trifluoromethylsulfonylbenzoic acid. To a boiling solution of 0.5 g of m-trifluoromethylmercaptobenzoic acid in 2 ml of glacial acetic acid was added 1 ml of 20% hydrogen peroxide dropwise. The mixture was heated on a water bath for 2 hr and boiled for 1 hr. It was diluted with 15 ml of water. The yield was 0.4 g (70%) and the m.p. 145-145.5° (from water).

Found %: S 12.35, 12.39. $C_8H_5O_4SF_3$. Calculated %: S 12.60.

SUMMARY

p-Trifluoromethylmercapto- and p-trifluoromethylsulfonylacetophenones and 2-amino- and 2-methyl-4-(p-trifluoromethylsulfonyl)-phenylthiazoles were synthesized. The latter base was used to prepare two dyes, namely, a symmetrical thiozolocarbocyanine and a merocyanine. Descriptions are given of o-, m-, and p-fluorophenyl trifluoromethyl sulfides and sulfones and also m-trifluoromethylmercapto- and m-trifluoromethylsulfonylbenzoic acids.

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NEW REACTION OF CHLOROACETONITRILE WITH HYDROGEN CHLORIDE AND ALCOHOLS

E. N. Zil'berman and A. Ya. Lazaris

In the present work we studied the products from the reaction of chloroacetonitrile and hydrogen chloride with water and primary alcohols.

We recently put forward the hypothesis [1] that in the preparation of amide hydrochlorides from nitriles, hydrogen chloride, and water, the formation of chloroimonium chlorides [2] as intermediate reaction products is not essential; in some cases, the unstable molecular compounds $RCN \cdot HCl$ may react directly with water with the formation of amide hydrochlorides. Since chloroacetonitrile, like other chloro derivatives of acetonitrile, reacts comparatively readily with hydrogen chloride and bromide to form salts with the composition $2RCN \cdot nHX$ [3, 4], which differ fundamentally from chlorimonium chlorides, it seemed interesting to us to confirm the above hypotheses experimentally with the reaction of chloroacetonitrile.

It was reported previously [5] that when hydrogen chloride is passed into an ether solution of equimolar amounts of chloroacetonitrile and water, chloroacetamide and chloroacetamide hydrochloride are formed. In the present work it was shown that if a solution of chloroacetonitrile was saturated with HCl and water added sometime later, a mixture of the secondary amide $ClCH_2CONHCOCH_2Cl$, a salt with the composition $2ClCH_2CH \cdot 3HCl$ and ammonium chloride was formed. When treated with excess water, this mixture was converted to dichlorodiacetamide and ammonium chloride. Thus, depending on the order of addition of the reagents, chloroacetonitrile, hydrogen chloride, and water react in two different directions and a primary amide is formed only when the possibility of the formation of stable salt-like products from the reaction of chloroacetonitrile and hydrogen chloride is eliminated.

By treatment of chloroacetonitrile with hydrogen chloride both in the absence of solvent and in its presence, we were unable to obtain the compound $2RCN \cdot HCl$, which was described by Grundmann and his co-workers [4], but isolated a compound of the composition $2RCN \cdot 3HCl$ (I). As the salt (I), like Grundmann's salt, was converted to a secondary amide by treatment with water, the two salts have analogous structures. Therefore, compound (I) may be assigned such structural formulas as (A) or (B), for example.

$$\left[\begin{array}{c} ClCH_2C=NH-CCH_2Cl \\ | \quad\quad\quad\; \| \\ Cl \quad\quad\quad NH \cdot HCl \end{array} \right]^+ Cl^- \quad\quad \left[\begin{array}{c} ClCH_2C=N-CCH_2Cl \\ | \quad\quad\quad\; \| \\ Cl \quad\quad\quad NH \cdot HCl \end{array} \right] \cdot HCl$$

$$\text{(A)} \quad\quad\quad\quad\quad\quad\quad\quad\quad \text{(B)}$$
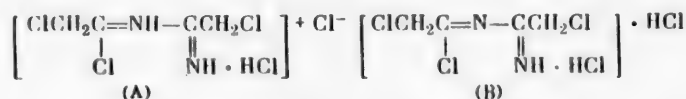
As is known, passing HCl into an equimolecular mixture of chloroacetonitrile and alcohol forms the hydrochloride of the imino ester of chloroacetic acid. By dissolving the salt (I) in anhydrous butanol, we obtained an acetic acid. By dissolving the salt (I) in anhydrous butanol, we obtained an almost theoretical yield on nitrogen of chloroacetamidine hydrochloride (II). In addition to the starting alcohol, the liquid part of the reaction mixture also contained butyl chloroacetate and dibutyl ether. As the components of the liquid part of the reaction products form azeotropic mixtures [6] they were identified by chromatography (see figure). Butyl chloroacetate was isolated in a pure state.

Solution of the salt (I) in ethanol and n-octanol also gave almost theoretical yields of chloroacetamidine hydrochloride. The amidine (II) was not formed when the salt (I) was treated with anhydrous methanol, but we obtained a stable crystalline compound with the composition $2ClCH_2CN \cdot 2CH_3OH \cdot HCl$ (III). The salt (III) was converted to chloroacetamidine hydrochloride (II) in a high yield (on nitrogen) only in the presence of water. It must be assumed that the salt (III), which is stable in the case of methanol, plays the part of an intermediate compound in reactions with higher alcohols. Thus, if the reaction of two alcohol molecules with the salt (I) is required for the formation of (III), then three alcohol molecules must participate in the direct formation of the amidine (II).

$$(I) + ROH \rightarrow ClCH_2C{\overset{\diagup NH \cdot HCl}{\diagdown NH_2}} + ClCH_2CO_2R +$$

$$(II)$$

$$ROR + 2HCl$$
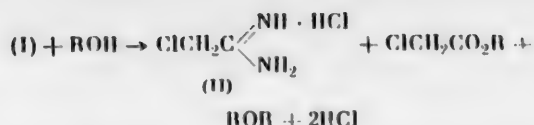
The formation of not the ortho ester, but a mixture of the ester and the ether together with the amidine during the alcoholysis of the salt (I), which has structure (A) or (B), agrees with some earlier data. A similar phenomenon was observed in the reaction of salts of some imino ethers with alcohols, when a mixture of the ester and ether was formed instead of ortho esters [7].

The reaction described is a convenient preparative method of synthesizing (II). The normal method of preparing (II) by treatment of a salt of an imino ether with alcoholic ammonia is inconvenient, as the ammonia produces strong tar formation, the product requires purification, and its yield does not exceed 30% [8]. Apart from giving a high yield, the synthesis method proposed in the present work gives a product which does not require purification and is quite suitable for subsequent use.

The authors would like to thank V. I. Kalmanovskii for help and valuable advice in the chromatographic analysis.

EXPERIMENTAL

Reaction of chloroacetonitrile with HCl and water. a) A solution of 1.5 g of the dry nitrile in 3 ml of absolute ether was saturated with dry HCl at 0°. The solution obtained was left at -15 to -10° for 2 days. We obtained 2.5 g (90%) of (I) as a white crystalline substance with m.p. 132-134° (with decomp.).

Found %: Cl' (ionic) 41.00; N 10.74. $C_4H_4Cl_2N_2 \cdot 3HCl$. Calculated %: Cl' (ionic) 40.88; N 10.74.

A 1 g sample of the salt (I) obtained was dissolved in 5 ml of water and the white precipitate collected and dried. We obtained 0.50 g of dichlorodiacetamide with m.p. 196° (according to data in [3], 195°). The filtrate was evaporated and treated with acetone. From the acetone we isolated a further 0.04 g of dichlorodiacetamide. The total yield was 0.54 g (83%). The residue after treatment with acetone was ammonium chloride (0.20 g, 99%).
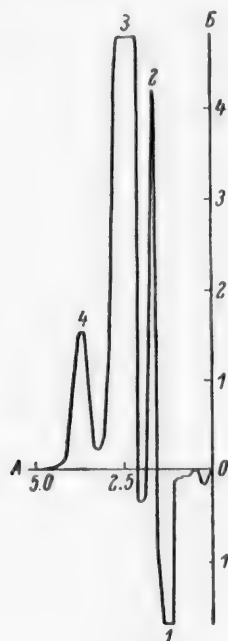
b) A solution of 1.5 g of chloroacetonitrile in 10 ml of ether was saturated with dry HCl at 0° and left at this temperature for 2 days and then 0.18 g of water was added to the still homogeneous solution. The reaction mixture was kept at 0° for 2 days. From the mixture we isolated 2.19 g of a precipitate containing 36.27% of Cl' and 10.52% of N. Hydrolysis of 1.88 g of this salt yielded 0.72 g of dichlorodiacetamide, which was analogous to that described above.

Reaction of chloroacetonitrile with HCl and butanol. To 16.3 g of the salt (I) was added 35 ml of anhydrous n-butanol. The mixture was shaken until the salt dissolved completely and then left at room temperature for a day. The solution was evaporated in vacuum (5 mm) with the liquid part collected in a trap cooled in a mixture of dry ice and acetone. The solid residue was washed with ether and dried. We isolated 8 g of chloroacetamidine hydrochloride (II) (49% on the nitrile and 98% on nitrogen) with m.p. 96-98° (according to data in [8], 101-103°). A mixed melting point with the product obtained from the imino ether hydrochloride [8] was not depressed.

Found %: C 18.10; H 4.65; N 21.56; Cl 54.48. $C_2H_6N_2Cl_2$. Calculated %: C 18.60; H 4.65; N 21.79; Cl 55.03.

The liquid part of the reaction products was washed with sodium carbonate solution and water for the removal of HCl and then distilled to give two fractions: 1st, 90-170° and 2nd, 170-173°. The second fraction was washed carefully with water and dried. We obtained 2 g of a substance which was identified as butyl chloroacetate with b.p. 173-175° (according to literature data [6], 175°), d_4^{20} 1.0412, n_D^{20} 1.4270, MR$_D$ 37.05; calc. 36.44.

Found %: Cl 23.03. $C_6H_{11}O_2Cl$. Calculated %: Cl 23.59.

Chromatogram of liquid part (1st fraction) of reaction mixture from chloroacetonitrile, HCl, and n-butanol. A) time (min); B) detector reading (mv); 1)Water; 2) n-butanol; 3) dibutyl ether; 4) butyl chloroacetate.

It was not possible to isolate pure substances by distillation of the 1st fraction to give narrower fractions.

The 1st fraction was analyzed chromatographically on a Griffin VPC MK II B chromatograph with a U-shaped column, 2 m in length and 4 mm in diameter, with kieselguhr as the adsorbant and dibutyl phthalate (30%) as the stationary phase. The elution gas was nitrogen, the gas flow rate 1.1 liter/hr, the temperature 135°, the pressure at the inlet 150 mm Hg, and the sensitivity of the instrument x1 with a thermal conductivity detector. Three components apart from water were found on the chromatogram (figure), one of them in a predominant amount. Chromatograms of pure n-butanol, dibutyl ether, butyl chloroacetate, water, and an artificial mixture of these compounds were obtained. The chromatograms of the artificial and the reaction mixtures were analogous. The retention times (corresponding peaks on the figure) of all the components of the two mixtures coincided.

Reaction of chloroacetonitrile with HCl and methanol. A solution of 10 g of the salt (I) in 20 ml of anhydrous methanol was left at room temperature for a day. Evaporation of the methanol in vacuum yielded 4.98 g (50%) of the salt (III) as a white crystalline powder with m.p. 107-108° (with decomp.).

Found %: C 28.64; H 5.61; N 11.57; Cl 41.40. $C_4H_{13}N_2Cl_3$. Calculated %: Cl 28.62; H 5.56; N 11.13; Cl 42.34.

A 2 g sample of (III) was dissolved in 10 ml of water and the solution left at room temperature for 2 days. Evaporation in vacuum yielded 0.92 g (90%) of chloroacetamidine hydrochloride (II).

SUMMARY

1. It was found that depending on the order of addition of the reagents, the reaction of chloroacetonitrile with hydrogen chloride and water proceeds in different directions with the formation of either a primary or a secondary amide.

2. It was found that the reaction product of chloroacetonitrile and hydrogen chloride reacts with primary alcohols to form chloroacetamidine hydrochloride; the chloroacetic ester and the corresponding ether are also formed.

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SYNTHESIS OF ESTERS AND OTHER DERIVATIVES OF CARBOXYLIC ACIDS FROM CARBON MONOXIDE, OLEFINS, AND ACYLATING COMPOUNDS UNDER ACID CATALYSIS CONDITIONS

V. SYNTHESIS OF ESTERS OF CIS-DECALIN-9-CARBOXYLIC ACID FROM CYCLOPENTENE AND 4,7-ENDOMETHYLENEHYDRINDANCARBOXYLIC ACID FROM 4, 5, 6, 7, 8, 9,-HEXAHYDRO-4,7-ENDOMETHYLENEINDENE

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It was shown previously [1] that cyclohexene and cyclopentene behave differently in the two-stage carbalkoxylation of olefins with carbon monoxide in the presence of concentrated sulfuric acid at 20-40° and a CO pressure of 80 atm [2]. From cyclohexene there was obtained about a 50% yield (on the starting cycloolefin) of a mixture of methyl or ethyl esters, in which the product of direct carbalkoxylation, namely, the cyclohexanecarboxylic ester, and the ester of the isomeric 1-methylcyclopentane-1-carboxylic acid were in a volume ratio of 4 : 5 and formed 90% (vol.) of the mixture. By direct carbalkoxylation, cyclopentene gave only ~10% yield (on the starting cycloolefin) of the cyclopentanecarboxylic ester. High-boiling products, which were not examined more closely, were obtained at the same time in about the same yield. It was naturally assumed that the latter were carbalkoxylation products of the dimeric form of the starting cyclopentene, formed during the reaction under the action of the sulfuric acid. In particular, these could be esters of decalin-9-carboxylic acid, most probably the cis-form. Analogy with literature data leads to the same conclusion. Thus, according to Koch and Haaf [3], cis-decalin-9-carboxylic acid is obtained by the same method not only from β-decalol or $\Delta^{9(10)}$-octalin (in 65-95% yield together with 10-20% of the trans-form of the acid), but also from 2-cyclopentylcyclopentanol-1 (~90% yield), cyclopentanol, and cyclopentene. The yield of cis-decalin-9-carboxylic acid from cyclopentanol was 11% with the simultaneous formation of cyclopentanecarboxylic acid in 15% yield, while the yield was even much less from cyclopentene; a mixture containing 90% (vol.) of cyclopentanecarboxylic acid and 10% of cis-decalin-9-carboxylic acid was obtained in 6% yield. In all these cases the synthesis method consisted of treatment of the alcohol or olefin with formic acid in the presence of a large excess of concentrated sulfuric acid at atmospheric pressure.

In the present work we investigated the possibility of the formation of cis-decalin-9-carboxylic esters from cyclopentene under the conditions we developed for the synthesis of esters [2].

Cyclopentene was carbalkoxylated in the usual way to give a 54% yield on the carbon monoxide absorbed or 24% on the starting cyclopentene of a mixture of ~50% by volume of methyl cyclopentanecarboxylate and ~40% of methyl cis-decalin-9-carboxylate. The former ester was formed by direct carbalkoxylation of cyclopentene without isomerization, in contrast to the cyclohexanecarboxylic ester, which was obtained previously from cyclohexene [1].
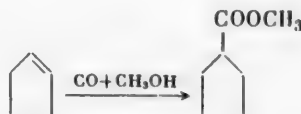
The second ester was evidently formed as a result of dimerization of the cyclopentene and subsequent carbalkoxylation of the dimeric form. The latter may be imagined as a system of two uncondensed five-membered rings, for example, 2-cyclopentylcyclopentene-1, which isomerizes to $\Delta^{9(10)}$-octalin.
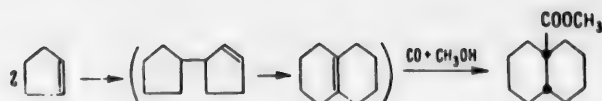
The fact that a system of two uncondensed five-membered rings is readily converted into $\Delta^{9(10)}$-octalin is shown by the exceptionally high yield of cis-decalin-9-carboxylic acid from 2-cyclopentylcyclopentanol-1 [3]. In this connection it seemed interesting to investigate the behavior of an unsaturated five-membered ring in a condensed system under carbalkoxylation conditions. For this purpose we used 4,5,6,7,8,9-hexahydro-4,7-endomethyleneindene (dihydrodicyclopentadiene), whose carbalkoxylation gave a 60-92% yield on the carbon monoxide absorbed and 44-68% on the starting tricycloolefin of a mixture of methyl or ethyl esters containing up to 74% by volume of the ester of 4,7-endomethylenehydrindancarboxylic acid.
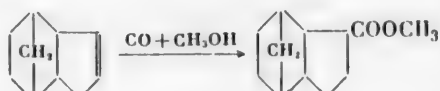
The position of the carbalkoxyl group in the five-membered ring was not determined. We should note that for 4,7-endomethylenehydrindancarboxylic acid and its esters there are two possible isomers, which differ in the position of the carboxyl group in the five-membered ring. In addition to optical isomerism, both of these isomers may have endo- and exo(α and β)-forms, which differ in the steric position of the five-membered ring relative to the methylene bridge. However, the endo- form is the usual one. Thus, in the condensed ring system of dihydrocyclopentadiene, the unsaturated five-membered ring undergoes carbalkoxylation more readily than cyclopentene itself.

EXPERIMENTAL

The starting cyclopentene (b.p. 44-45° at 760 mm, n_D^{20} 1.4228, d_4^{20} 0.7717, bromine number 223.5, and 97.5% unsaturated) was synthesized in about 60% yield by hydrogenation of cyclopentadiene (b.p. 41-42° at 760 mm, n_D^{20} 1.4461, d_4^{20} 0.7985, obtained by depolymerization of dicyclopentadiene [4]) in an autoclave at room temperature and 80 atm over skeletal nickel [5]. Dihydrodicyclopentadiene (4,5,6,7,8,9-hexahydro-4,7-endomethyleneindene) with m.p. 50-51° and b.p. 70-72° at 12 mm was obtained in 84% yield by hydrogenation of dicyclopentadiene (m.p. 33.5°) in alcohol solution (1 : 1) at room temperature and 100 atm over skeletal nickel. Melting points of 50-50.5 and 32° have been reported for dihydrodicyclopentadiene and dicyclopentadiene, respectively [6].

Carbomethoxylation of cyclopentene. Into a 1 liter stainless steel autoclave, fitted with a turbine mixer (800 rev/min) and a drop injector, was placed 0.5 liter of concentrated sulfuric acid and carbon monoxide introduced to a pressure of 76 atm. Then 250 ml of cyclopentene was introduced through the drop injector over a period of an hour and thereupon the pressure in the autoclave fell to 29 atm. The cyclopentene dissolved completely in the sulfuric acid with a corresponding increase in the volume of the reaction mixture. When the absorption of carbon monoxide had ceased (28 liters of CO was absorbed), the reaction mixture was removed from the autoclave and 300 ml of methanol and 1.5 liter of water were added to it. We isolated 90 ml of methyl esters of carboxylic acids, which represents 54.0% yield on the carbon monoxide absorbed and 24.3% on the starting cyclopentene.*

The mixture of esters obtained was distilled from a Favorskii flask at 3 mm and then fractionated on a column with an efficienty of 90 theoretical plates. We obtained two main fractions: the 1st (b.p. 158.2° at 760 mm, n_D^{20} 1.4360, d_4^{20} 0.9859) constituted ~50% and the 2nd fraction (b.p. 107-110° at 8 mm, n_D^{20} 1.4822, d_4^{20} 1.0257) ~40% of the volume of the total mixture of esters. From these fractions we prepared anilides [2], which were recrystallized to constant melting point from alcohol. These fractions were also hydrolyzed by boiling for 10 hr with 20% alcohol solution of KOH and the solutions of potassium salts of the carboxylic acids obtained were treated with 30% sulfuric acid solution. The carboxylic acids liberated were dissolved in hexane, dried over anhydrous sodium sulfate, and after removal of the hexane, vacuum distilled from a Favorskii flask. The carboxylic acids were used to prepare

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* The yield was a factor 2-3 lower than for aliphatic olefins and cyclohexene [1, 2].

anilides and amides. The 1st fraction consisted of methyl cyclopentanecarboxylate. The anilide obtained from this ester had m.p. 160.5° (according to [7]: m.p. 160.1-161.2°). Hydrolysis of the 1st fraction yielded cyclopentane-carboxylic acid with b.p. 103.5-104.0° at 10 mm, n_D^{20} 1.4538, d_4^{20} 1.0515; amide, m.p. 178° according to [8] cyclo-pentanecarboxylic acid has b.p. 104° at 11 mm, n_D^{20} 1.4532 [9], d_4^{20} 1.0510 [8]; amide, m.p. 179° [8]. A mixed meling point of the anilides prepared from the ester and from the acid was not depressed.

The 2nd fraction was methyl cis-decalin-9-carboxylate. According to [3], this ester has b.p. 130° at 20 mm, and n_D^{20} 1.4830. The anilide prepared from the 2nd fraction had m.p. 172°; the acid obtained by hydrolysis of this fraction had m.p. 122° and b.p. 170-172° at 8 mm, while its amide had m.p. 129.5°. According to [10], cis-decalin-9-carboxylic acid has m.p. 122.0-122.3° and its amide has m.p. 129.7-130.5°. A mixed melting point of the anilides from the ester and the acid was not depressed.

Carbomethoxylation of dihydrodicyclopentadiene (4,5,6,7,8,9-hexahydro-4,7-endomethyleneindene). By the method described above, from 200 g of dihydrodicyclopentadiene dissolved in 100 ml of n-hexane, 22.8 liters of carbon monoxide (initial CO pressure 85 atm and final pressure 52 atm), 400 ml of conc. H_2SO_4, and 200 ml of methanol we obtained 170 ml of a mixture of methyl esters, which represents 92.2% yield on the carbon monoxide absorbed and 68.2% on the starting tricycloolefin. Fractionation of the mixture of esters yielded a fraction with b.p. 69-72° at 3 mm, n_D^{20} 1.4889; d_4^{20} 1.0652, which constituted 64% (vol.); it was methyl 4,7-endomethylenehy-drindancarboxylate, though the position of the carbomethoxyl group was not determined. It was reported [6] that methyl 4,7-endomethylenehydrindancarboxylate, also with the carbomethoxyl group in an undetermined position, has b.p. 97-99° at 2 mm. Hydrolysis of the methyl ester we obtained yielded 4,7-endomethylenehydrindancar-boxylic acid with m.p. 98° and b.p. 148-150° at 3 mm. The amide prepared from it had m.p. 160°. The 4,7-endo-methylenehydrindancarboxylic acid with the carboxyl group in an undetermined position reported in [6] had m.p. 102-103° and b.p. 131-132° at 1.5 mm.

Carbethoxylation of dihydrodicyclopentadiene. By the method given above, from 200 g of dihydrodicyclo-pentadiene dissolved in 100 ml of n-hexane, 24.2 liters of carbon monoxide (initial CO pressure 86 atm and final pressure 51 atm), 400 g of conc. H_2SO_4, and 250 ml of alcohol, we obtained 130 ml of a mixture of ethyl esters, which represents 60.2% yield on the carbon monoxide absorbed and 43.6% on the starting tricycloolefin. Distilla-tion of the mixture yielded a fraction with b.p. 103-104° at 3 mm, n_D^{20} 1.4859, d_4^{20} 1.0460, constituting 74.1% of the mixture by volume; it was ethyl 4,7-endomethylenehydrindancarboxylate, whose hydrolysis gave the same acid as that from the methyl ester described above. The anilides prepared from the two esters and directly from the two acid samples had m.p. 170° and a mixed melting point was not depressed.

SUMMARY

1. Carbomethoxylation of cyclopentene with carbon monoxide and methanol in the presence of concentrated sulfuric acod at 20-40° and 80 atm of CO gave a 24% yield on the starting cyclopentene of a mixture of esters, which consisted of 90% of the methyl esters of cis-decalin-9-carboxylic and cyclopentanecarboxylic acids (in a volume ratio of 4 : 5).

2. Carbalkoxylation of dihydrodicyclopentadiene (4,5,6,7,8,9-hexahydro-4,7-endomethyleneindene) under the same conditions gave 44% (68%) yields of a mixture of ethyl (methyl) esters, which contained 74 vol. % (64 vol. %) of 4,7-endomethylenehydrindancarboxylic ester.

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REACTION OF SULFUR DIOXIDE WITH SOME ALKYLENE OXIDES

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In the literature there is a series of patents describing the preparation of ethylene sulfite from ethylene oxide and sulfur dioxide. The reaction is carried out either without a catalyst [1] or in the presence of catalysts,and dimethylaniline, pyridine, amides, and phosphines have been proposed as catalysts [2]. When activated charcoal, alumina, and a series of salts are used as catalysts, dioxane is obtained together with ethylene sulfite [3].

The preparation of ethylene sulfite without catalysts and with dimethylaniline and pyridine as the catalysts, as described in the patents, could not be reproduced. It therefore seemed interesting to us to examine the reaction of ethylene oxide and other epoxides with SO_2 more closely.

The following quaternary ammonium salts were used as catalysts: tetraethylammonium chloride, tetraethylammonium bromide, tetraethylammonium iodide, triethyloctylammonium bromide, and triethylbenzylammonium chloride. All these ctalysts showed the same activity regardless of the organic and acid groups. Tetraethylammonium bromide was therefore used for subsequent experiments.

In the investigation of the reaction of ethylene oxide with SO_2, the effect of the reagent ratio was studied. The reaction was carried out both at room temperature and with heating. The result of the reaction was always the formation of a linear polyester of ethylene glycol and sulfurous acid, which formed a thick, vitreous, clear mass. No reaction occurred in control experiments under the same conditions, but without a catalyst. The polysulfite obtained was heated over a smoky flame. Ethylene sulfite and a lighter fraction, consisting of dioxane, then distilled. The experimental results on the preparation of ethylene sulfite are given in Table 1.

An attempt was made to prepare ethylene sulfite without pressure. For this purpose, SO_2 was passed into ethylene oxide,containing catalyst,at 0 to -5°. After evaporation of the unreacted substances, the residue was vacuum distilled. In this case, ethylene sulfite was obtained in 3.7% yield, calculated on the ethylene oxide taken.

TABLE 1. Effect of Reaction Conditions on Ethylene Sulfite Yield
(Catalyst concentration, 0.5% of the ethylene oxide taken; 18-20°)

Reagent ratio	Time (days)	Catalyst	Yield
Equimolar	5	$(C_2H_5)_4NBr$	56.5
	5	$(C_2H_5)_4NBr$	46.4
	5	$(C_2H_5)_4NBr$	51.2
	6	$(C_2H_5)_4NCl$	42.2
	6	$(C_2H_5)_4NI$	44.5 *
	6	$[C_8H_{17}N(C_2H_5)_3]Br$	44.5
	6	$[C_6H_5CH_2N(C_2H_5)_3]Cl$	47.7
	12	$(C_2H_5)_4NBr$	48.7
10% excess of ethylene oxide	5	$(C_2H_5)_4NBr$	43.7
	6	$(C_2H_5)_4NBr$	52.7
	14	$(C_2H_5)_4NBr$	39.8
100% excess of ethylene oxide	4 months	$(C_2H_5)_4NBr$	58.2
10% excess of SO_2	5	$(C_2H_5)_4NBr$	46.8
	6	$(C_2H_5)_4NBr$	44.2
	14	$(C_2H_5)_4NBr$	37.0

* Catalyst concentration, 0.3% of the ethylene oxide taken.

TABLE 2. Reaction Conditions and Physicochemical Constants of Sulfites Obtained

Epoxy compound	Amount of reagents (g)		Reaction conditions		Cyclic sulfite obtained (g)	Physicochemical constants of sulfites									Literature reference
						found					literature data		calculated		
	epoxide	SO₂	temperature	time		boiling point (pressure in mm)	n_D^{21}	d_4	M (cryoscopic)	MR	boiling point (pressure in mm)	n_D^{25}	M	M.R. [11]	
Ethylene oxide { a	33.80	48.10	18—20°	5 days	44.10	55—57 (4)	1.4450	1.4375 (25°)	111	20.7	88° (52)	1.4450	108	20.5	[7]; [8] *
b	12.20	17.70	110—120	3 hr	15.30										
Propylene oxide { a	65.70	110.50	18—20	8 days	53.90	50—52 (4)	1.4350	1.2765 (25°)	124	25.3	92 (40)	1.4354	122	25.4	[9]
b	10.70	11.80	120	5 hr	10.00										
Epichlorohydrin	18.30	12.64	180—200	5 hr	22.40	81—84 (4)	1.4805	1.5136 (20°)	157.5	29.7	210 (760)	1.4807	156.5	30.2	[10]
Glycidol	32.75	28.30	80	8 hr	18.00	112—114 (3)	1.4723 (20°)	1.4862 (20°)	—	26.1	—	—	138	26.8	
Trimethylene oxide	3.60	5.50	110—120	12 hr	1.17	49—50 (4)	1.4500	—	123	—	90—92 (38)	1.4498	122	—	[9]

* According to literature data [8]: d_4^{25} 1.4320.

Propylene sulfite was obtained both at room temperature and at a high temperature. It was isolated both by direct vacuum distillation of the sirupy liquid obtained and with preliminary decomposition of the latter over a smoky flame. As in the case of ethylene sulfite, there also distilled a light fraction, which contained propionaldehyde, water, and a sulfur-free compound that has not been investigated more closely. When the reaction was carried out without pressure, the yield of propylene sulfite was greater than that of ethylene sulfite. After SO_2 had been passed through boiling propylene oxide for 5 hr, propylene sulfite was obtained in 23% yield, calculated on the propylene oxide taken.

The reaction of epichlorohydrin with SO_2 under pressure at 180-200° and without pressure at the boiling point of epichlorohydrin yielded 3-chloropropylene sulfite. When the synthesis was carried out without pressure, the sulfite yield was 13.8% yield on the epichlorohydrin taken.

It seemed interesting to treat glycidol with SO_2 for the preparation of 3-hydroxypropylene sulfite, which cannot be prepared by the usual method from glycerol and thionyl chloride. At a high temperature and in the presence of tetraethylammonium bromide, the reaction gave 3-hydroxypropylene sulfite, which has not been described previously.

The reaction of SO_2 with cyclohexene oxide both with heating and at room temperature formed a solid, vitreous, friable polysulfite, which was soluble in benzene. Its molecular weight, determined cryoscopically, was found to equal 985, which corresponds to approximately six monomeric cyclohexene sulfite molecules. In an attempt to isolate monomeric cyclohexene sulfite by heating the polymer on a smoky flame, we obtained cyclohexanediol and cyclopentaldehyde. This indicates that the linear polysulfite had a trans-configuration, which is in agreement with data on the pyrolysis of transcyclohexene sulfite [4]. Cyclopentaldehyde may be obtained from cyclohexanediol [6].

The reaction between SO_2 and stilbene oxide also gave a polymeric product.

Sulfur dioxide also reacted with β-oxides in the presence of quaternary ammonium salts. Trimethylene oxide and SO_2 yielded trimethylene sulfite. Tetrahydrofuran did not react under these conditions.

EXPERIMENTAL

The reagents and catalyst in the required ratios were sealed in glass ampoules. The ampoules were left at room temperature or shaken at a high temperature for various times. After the ampoules had been opened, their contents were vacuum distilled (if they were liquid)

TABLE 3. Results of Analyzing Cyclic Sulfites

Cyclic sulfite	Found (%)			Calculated (%)		
	C	H	S	C	H	S
Ethylene sulfite $C_2H_4O_3S$	22.42	3.60	30.50	22.20	3.70	29.80
Propylene sulfite $C_3H_6O_3S$	30.02	4.93	26.24	29.60	4.92	26.25
3-Chloropropylene sulfite $C_3H_5O_3SCl$*	28.88	3.30	19.70	23.00	3.20	20.02
3-Hydroxypropylene sulfite $C_3H_6O_4S$**	26.25	4.44	23.60	26.10	4.35	23.20
Trimethylene sulfite $C_3H_6O_3S$	29.30	5.33	26.25	29.60	4.92	26.25

* Found %: Cl 22.74; calculated 22.65.

** Found %: OH 0.73; calculated 0.72.

or first heated over a smoky flame to decompose the polyester. The results of the most characteristic experiments are given in Table 2. The elementary compositions of the sulfites obtained are given in Table 3.

Experiments on the reaction of alkylene oxides with SO_2 without pressure were carried out in a four-necked flask, fitted with a reflux condenser, stirrer, thermometer, and gas inlet tube with a porous plate for dispersion of the SO_2. The appropriate oxide and catalyst were placed in the flask and heated to boiling and SO_2 was passed in. After removal of the unreacted substances by distillation, the residue was vacuum distilled.

Thermal decomposition of polyethylene sulfite yielded a low-boiling fraction (21% on the polysulfite) consisting of 1,4-dioxane (b.p. 100-101°, n_D^{20} 1.4200), water, and acetaldehyde (3.1%), which was identified as the 2,4-dinitrophenylhydrazone (m.p. 146°). A mixed melting point with the 2,4-dinitrophenylhydrazone of acetaldehyde was not depressed.

Heating polypropylene sulfite yielded a fraction equal to 38% of the polysulfite taken. It consisted of 7.0% of water and 27% of propionaldehyde (2,4-dinitrophenylhydrazone with m.p. 155°; a mixed melting point with propionaldehyde 2,4-dinitrophenylhydrazone was not depressed). The remainder of the fraction consisted of a substance that distilled at 119-121°, which was not investigated more closely.

When heated, polycyclohexene sulfite decomposed to trans-1,2-cyclohexanediol with m.p. 102°. A mixed melting point with trans-1,2-cyclohexanediol, which was obtained by oxidation of cyclohexene with performic acid [5], was not depressed.

Found %: C 61.92; H 10.10. $C_6H_{12}O_2$. Calculated %: C 62.10; H 10.30.

In addition, we obtained cyclopentaldehyde, whose 2,4-dinitrophenylhydrazone had m.p. 135-138°.

Found %: N 20.47, 20.24. $C_{12}H_{14}O_4N_4$. Calculated %: N 20.10.

SUMMARY

1. A simple method was developed for the synthesis of cyclic alkylene sulfites by the reaction of α- or β-oxides of alkylenes with SO_2 in the presence of quaternary ammonium salts. Ethylene sulfite, propylene sulfite, 3-chloropropylene sulfite, 3-hydroxypropylene sulfite, and trimethylene sulfite were prepared.

2. It was shown that the reaction of alkylene oxides with SO_2 in the presence of quaternary ammonium salts forms linear polysulfites, which decompose on heating to the corresponding cyclic sulfites.

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DECOMPOSITION OF SOME LOW-MOLECULAR POLYSULFITES

G. A. Razuvaev, V. S. Étlis, and L. N. Grobov

As we have already reported [1], the reaction of olefin oxides with SO_2 in the presence of quaternary ammonium salts forms low-molecular polyesters of alkylene glycols and sulfurous acid. These esters decompose when heated to 400-450° with the distillation of cyclic glycol sulfites and a small amount of byproducts. It was also observed that polyethylene and polypropylene sulfites are converted to monomeric cyclic sulfites on standing in air. We explained this phenomenon by the action of atmospheric oxygen, as linear sulfites sealed in ampoules in a pure nitrogen atmosphere did not undergo this decomposition. The monomeric sulfite formed was found to contain peroxide compounds, which liberated iodine from acidified potassium iodide solution.

To demonstrate that the decomposition of the polysulfite was connected with the peroxide compounds detected, we synthesized a polysulfite in the presence of 0.1% of hydroquinone. The polysulfite stabilized in this way retained its linear polymeric structure even under the prolonged action of atmospheric oxygen.

In connection with the phenomena observed, it seemed interesting to us to study the effect of other peroxides and hydroperoxides on the decomposition of polysulfites. We studied the decomposition of the polysulfites by measuring the decrease in viscosity of their solutions in like monomeric sulfites in the presence of benzoyl peroxide, cyclohexanesulfonyl acetyl peroxide, bis(1-hydroperoxycyclohexyl) peroxide, cumene hydroperoxide, and tert-butyl hydroperoxide. The results of these investigations are illustrated in Figures 1 and 2.

The curves of the decrease in viscosity with time show that hydroperoxides are the most active initiators of the decomposition of the polyesters. Cyclohexanesulfonyl acetyl peroxide, which decomposes at the lowest temperature, was found to be the most active peroxide.

Fig. 1. Change in the viscosity of a solution of polyethylene sulfite in ethylene sulfite with time (temperature 40 ± 0.1°; solution concentration 4.35%). In the presence of: 1) 0.1% benzoyl peroxide; 2) 0.093 % cyclohexanesulfonyl acetyl peroxide; 3) 0.036% bis(1-hydroperoxycyclohexyl) peroxide.

Decomposition of the polyesters of glycols and sulfurous acid may also be produced by irradiation with ultraviolet light. The rate of decrease in the viscosity of a 5% solution of polysulfite in ethylene sulfite in a nitrogen atmosphere during irradiation with a PRK-2 quartz lamp is shown in Figure 2.

By using initiated depolymerization of polycyclohexene sulfite, obtained by the reaction of cyclohexene oxide with SO_2, we were able to prepare trans-cyclohexene sulfite, which could not be obtained by thermal decomposition of the polysulfite.

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The decomposition of the polysulfite was carried out by keeping the solution for a definite time in a thermostatted bath at a temperature controlled to ±0.1° and then the relative viscosity was measured. The amount of initiator used was such that the active oxygen content was the same in all cases.

Decomposition under the action of ultraviolet light was carried out in a quartz tube in a pure nitrogen atmosphere. At definite intervals, 5 ml samples of solution were taken and the viscosity determined.

For the preparation of monomeric ethylene sulfite, 47 g of the polyester was heated with 0.2 % of bis(1-hydroperoxycyclohexyl) peroxide dissolved in 1 ml of monomeric sulfite on a boiling water bath for 15 hr. Vacuum distillation yielded 32.15 g of ethylene sulfite.
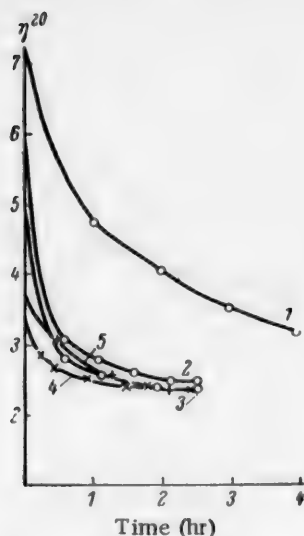
Fig. 2. Change in the viscosity of solutions of polyalkylene sulfites in alkylene sulfites with time. 1) Solution of polyethylene sulfite at 20° in ultraviolet light ($\underline{c}$ 5%); 2) solution of polyethylene sulfite at 40° ($\underline{c}$ 5%) in the presence of 0.065% of cumene hydroperoxide; 3) solution of polyethylene sulfite ($\underline{c}$ 5%) at 40° in the presence of 0.038% of tert-butyl hydro peroxide; 4) solution of polyethylene sulfite ($\underline{c}$ 4.35%) at 40° in the presence of 0.036% of bis(1-hydroperoxycyclohexyl) peroxide; 5) solution of polypropylene sulfite ($\underline{c}$ 10%) at 40° in the presence of 0.036% of bis(1-hydroperoxycyclohexyl) peroxide.

B. p. 55-57° at 4 mm, n_D^{25} 1.4450, d_4^{25} 1.4375.

Found %: C 22.42; H 3.60; S 30.10. $C_2H_4O_3S$. Calculated %: C 22.20; H 3.70; S 29.80.

Trans-1,2-cyclohexene sulfite was obtained by heating 14 g of poly-1,2-cyclohexene sulfite in 50 ml of methylene chloride in the presence of 0.2% of bis(1-hydroperoxycyclohexyl) peroxide on a water bath for 12 hr. After removal of the solvent, the residue was vacuum distilled. We isolated 6.8 g of a fraction with b.p. 100-103° at 5 mm and n_D^{20} 1.4843.

Literature data: b.p. 94-96° (2 mm), n_D^{20} 1.4847 [2].

Found %: C 44.21; H 6.39; S 19.70. $C_6H_{10}O_3S$. Calculated %: C 44.40; H 6.17; S 19.17.

To prevent oxidative destruction of polysulfite, 0.1% of hydroquinone (on the sum of the reactants) was added to the reaction mixture during the synthesis.

SUMMARY

1. Polyesters of 1,2-glycols and sulfurous acid decompose to monomeric cyclic alkylene sulfites under the action of atmospheric oxygen with the intermediate formation of hydroperoxides. The decomposition is considerably accelerated in the presence of peroxides and hydroperoxides. The latter are much more active. It is possible to obtain a polyester stable in air by introducing antioxidants during the synthesis of the polysulfite.

2. The decomposition of polysulfites in the presence of hydroperoxides may be used as a preparative method for synthesizing alkylene sulfites, starting from epoxides and SO_2.

LITERATURE CITED

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2. C. C. Price and G. Berti, J. Am. Chem. Soc. 76, 1211 (1954).

STERIC HINDRANCE IN CONJUGATION CHAINS
OF POLYMETHYNE DYES

III. ANHYDRO BASES OF HYDROXYSTYRYL DERIVATIVES OF NITROGEN
HETEROCYCLES

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Following the work of A. I. Kiprianov and V. E. Petrun'kin [1], the anhydro bases of hydroxy styryl derivatives, of which the dye (I) is an example, became the subject of a large number of investigations on the solvochromism of dyes [2].
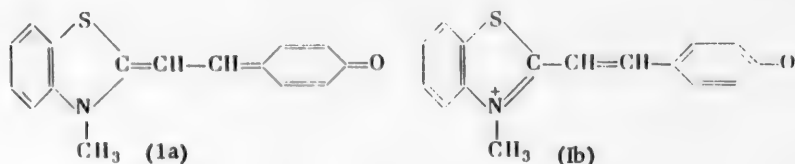
The change in the color of their solutions with a change from one solvent to another is explained by the change in the electronic structure of their molecules in relation to the polarizing power of the solvent. The deepest and most intense color was observed in the solvent in which the two structures, namely, the nonpolar (Ia) and the bipolar (Ib), were present in equal amounts. Dyes in whose structures the nonpolar form predominates became deeper in color with a change from less to more polar solvents (positive solvochromism); dyes in whose structure the bipolar form predominates became lighter in color with the same change (negative solvochromism) [3]. Simultaneously with polarization, the order of all the bonds in the chain changes in the molecule of the anhydro base (I) under the influence of the solvent. The order of the bond between the thiazole ring and the neighbouring methyne group approaches one in a strongly polarizing solvent, while it approaches two in a weakly polar solvent and takes on all possible intermediate values in other solvents.

The question arose as to how the appearance of steric hindrance in the conjugation chain would affect the solvochromism of anhydro bases of hydroxystyryls of type (I). This is not difficult to predict in general outline. If a methyl group is introduced into the β-position of the anhydro base of the hydroxystyryl (I), we obtain compound (II), in which steric hindrance arises between the methyl group introduced, on the one hand, and the sulfur atom and methyl at the nitrogen atom, on the other, and this forces the benzthiazole nucleus to rotate a certain angle about the bond connecting it to the adjacent carbon atom of the chain.
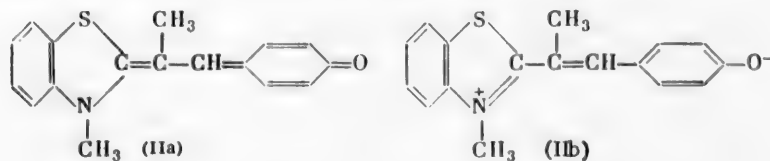
TABLE 1

Solvent	Absorption maximum (mμ)		Δ (mμ)
	(I)	(II)	
H_2O	492 (0.54)	427 (0.19)	—65
CH_3OH	538 (0.88)	481 (0.09)	—57
CH_3COCH_3	556 (1.04)	560 (0.05)	+ 4
$CHCl_3$	563 (0.94)	575 (0.22)	+12

TABLE 2

Solvent	Absorption maxima (mμ)		Δ (mμ)
	(I)	(III)	
H_2O	492 (0.51)	470 (0.33)	—22
CH_3OH	538 (0.88)	522 (0.32)	—16
CH_3COCH_3	556 (1.04)	560 (—)	+ 4
$CHCl_3$	563 (0.94)	572 (0.28)	+ 9

In polar solvents in which this bond will tend to a single bond, there should be a displacement of the absorption maximum toward short wavelengths with a change from (I) to (II). In less polar solvents in which the order of the bond about which rotation of the nucleus occurs approaches 1.5 or more, the absorption maximum should be displaced toward longer wavelengths. A fall in absorption intensity is to be expected in some cases [4].

These hypotheses are confirmed by experiment. Table 1 gives the absorption maxima we found for compounds (I) and (II) in water, methanol, acetone, and chloroform. The corresponding molecular extinctions ($\epsilon \cdot 10^{-5}$) are given in brackets.* The column headed Δ gives the displacements of the absorption maxima with a change from (I) to (II).

Both preparations (I) and (II) showed negative solvochromism in all the solvents given in Table 1. However, the displacements of the maxima Δ in water and methanol were high negative values (hypsochromic displacements), but became positive in acetone and chloroform (bathochromic). This means that in the last two solvents, the order of the bond about which rotation of the benzthiazole nucleus occurs approaches 1.5.

In preparation (III), steric hindrance between the methyl group and the hydrogen atoms of the benzene (quinone) nucleus force this nucleus to rotate a certain angle about the bond "b".

(IIIa)   (IIIb)
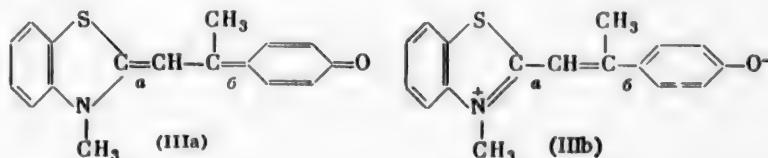
* As the anhydro bases of hydroxystyryls in whose conjugation chains there is steric hindrance are rapidly decolorized in solutions, the molecular extinctions are rough values.

As the order of bond "b" should be the same as that of bond "a" (or close to it) in any solvent, it was to be expected that with a change from (I) to (III), the displacements of the absorption maxima Δ would have the same signs as in Table 1, but be less in magnitude, as the steric hindrance in (III) is not so great as in (II). The data given in Table 2 are in agreement with this.

A comparison of the range of changes in the absorption maxima with a change from water to chloroform for the preparations (I) and (II) with that for the preparations (I) and (III) shows that this range (solvochromism capacity) increases with the appearance of steric hindrance in the molecule.
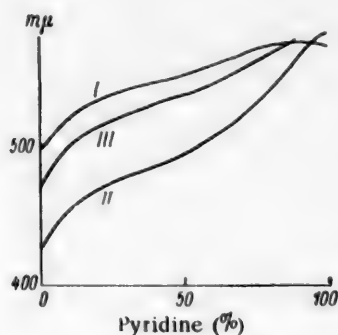
Fig. 1
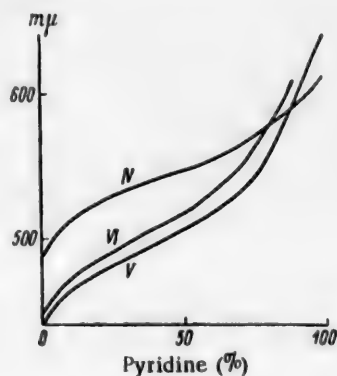
Fig. 2
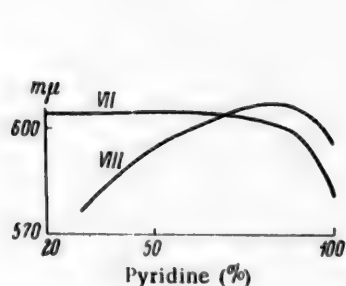
Fig. 3
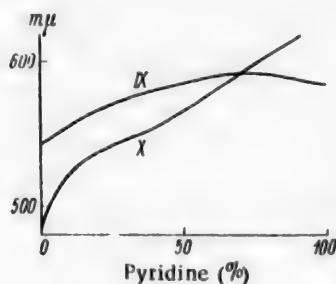
Fig. 4
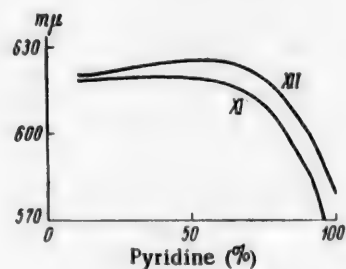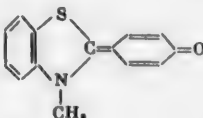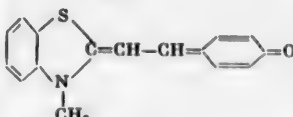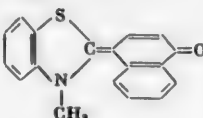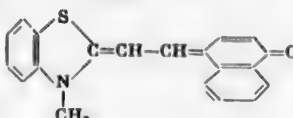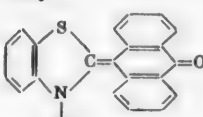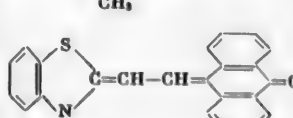
Fig. 5

Brooker et al. [2] investigated the solvochromism of a series of dyes in mixtures of a strongly polar and a weakly polar solvent such as pyridine and water, rather than individual solvents of different polarities. Below we give the results of an investigation of light absorption by anhydro bases of hydroxystyryls in mixtures of pyridine and water. Data of this type are convenient in that they can be presented as continuous curves with the wavelengths corresponding to the absorption maxima along the ordinate axis and the pyridine concentration in percent along the abscissa. The form of the curves shows the type of solvochromism: a rise in the curve indicates negative solvo-chromism and a fall, positive solvochromism. Figure 1 shows the change in the absorption maxima in mixtures of pyridine and water for the three preparations examined above (I, II, and III).

The rules observed in Tables 1 and 2 become even more obvious in the curves in figure 1. Over a large part of the curve, the dye (I) shows negative solvochromism, but beginning at 85% pyridine, its solvochromism changes to positive. The corresponding curves of (II) and (III) lie below the curve of (I) (rotation of the nucleus about a single or almost single bond). However, at 85% pyridine, the curve of (III) intersects the curve of (I) and at 94% pyridine there is a similar intersection by the curve of (II). At pyridine concentrations corresponding to the points of intersection of the curves, the order of the bonds about which rotation of the nucleus occurs is such that no dis-placement of the absorption maximum is produced. We will subsequently refer to such points as points of zero

TABLE 3

Substance No.	Structural formula	Absorption maxima (mμ)					Type of solvochromism
		$CH_3OH+HCl$	CH_3OH	CH_3COCH_3	$CHCl_3$	C_6H_6	
(XX)		340 (0.28)	415 (0.41)	449 (0.60)	457 (0.43)	459 (0.35)	Negative
(I)		420 (0.40)	538 (0.88)	556 (1.04)	563 (0.94)	548 —	Intermediate
(XXI)		373 (0.12)	467 (0.33)	482 (0.51)	493 (0.39)	485 (0.34)	Intermediate
(VII)		483 (0.33)	596 (1.28)	563 (0.78)	567 (0.73)	538 (0.63)	Positive
(XXII)		415 (0.06)	558 (0.07)	551 (0.08)	551 (0.06)	518 (0.07)	Positive
(XXIII)		560 (0.07)	558 (0.34)	537 (0.39)	537 (0.37)	525 (0.37)	Positive

maximum displacement. We do not know the order of the bond corresponding to these points, but we do know that it lies below 1.5, as the introduction of methyl groups into the α- and γ-positions of a symmetrical thiacarbocyanine, for which the order of the bonds in the chain equals 1.5 [5], gives a bathochromic displacement of the absorption maximum [6].

Figure 2 gives analogous curves for solutions of the anhydro bases (IV, V, and VI).
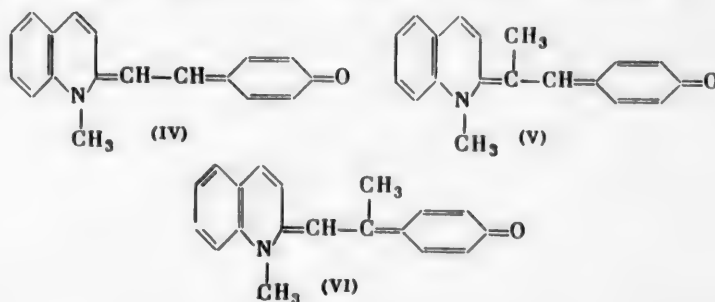
The form of these curves is very similar to that of the curves (I, II, and III) in figure 1. The points of zero displacement lie at 80% pyridine for (VI) and 86% pyridine for (V).

Replacement of the benzene nucleus in the anhydro base of the hydroxystyryl (I) by a naphthalene nucleus leads to preparation (VII), whose solvochromism is intermediate between negative and positive [7].

C=CH—CH—⟩=O   (VII)
C—C—CH=⟩=O   with CH₃   (VIII)
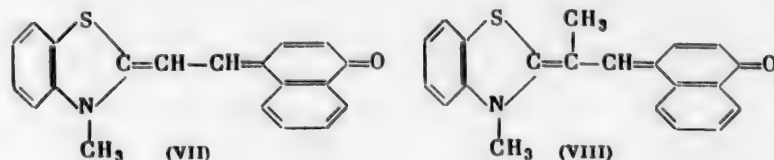
The corresponding curve in figure 3 is almost horizontal up to 70% pyridine and then falls rapidly. It is precisely here at 70% pyridine that this curve intersects (point of zero maximum displacement) the curve of the methyl derivative (VIII).

It is known that the solvochromism of anhydro bases of hydroxystyryls may be affected by the introduction of polar substituents into their molecules [8].

NO_2 ... C=CH—CH=⟩=O   (IX)
NO_2 ... C=C—CH=⟩=O with CH_3 (X)
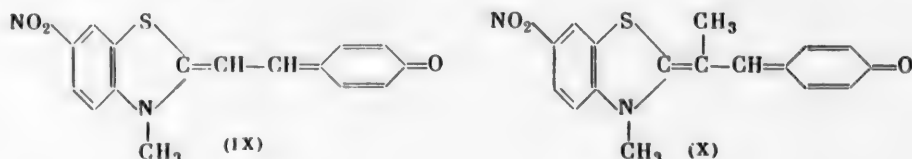
The nitro group in the dye (IX) decreases the polarity of the molecule, so that the solvochromism of this preparation becomes intermediate: its curve gradually rises up to 70% pyridine and then falls slowly (Fig. 4). For the most part, the corresponding curve of the methyl derivative (X) lies below the curve of (IX)[the hypsochromic displacements of the maximum are considerably lower here than for preparation (II), Fig. 1] and intersects it at 70% pyridine.

Figure 5 gives curves of the change in the absorption maxima in mixtures of water and pyridine for the anhydro bases of the hydroxystyryls (XI) and (XII).

NO_2 ... C=CH—CH=⟩=O   (XI)
NO_2 ... C=C—CH=⟩=O with CH_3 (XII)
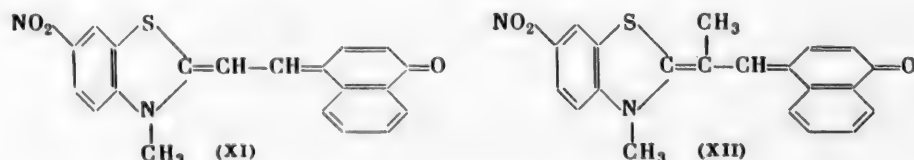
In these compounds, the polar form of the molecule is suppressed even more than in (IX). Over the whole range of the curve, the preparation (XI) shows positive solvochromism. At all pyridine concentrations, the change from (XI) to its methyl derivative (XII) leads to a bathochromic displacement of the absorption maximum. Curves (XI) and (XII) do not interesect (measurements could not be made in water because of the insolubility of the preparations).

Unlike the nitro group, the dimethylamino group sharply increases the polarity of the molecule of an anhydro base of a hydroxystyryl. The preparation (XIII) shows predominant negative solvochromism. The hypsochromic displacements with a change from (XIII) to its methyl derivative (XIV) are very great (Fig. 6) and it is only above 87% pyridine (point of zero maximum displacement) that they become bathochromic.

(XIII)

(XIV)
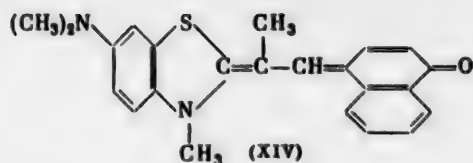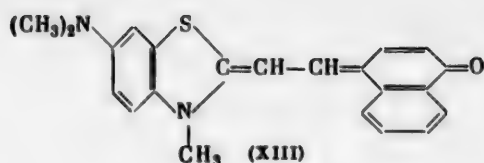
The molecule of the preparation (XV) is even more polarized. It shows negative solvochromism in all mixtures of water and pyridine. Replacement of hydrogen by a methyl group (preparation XVI) gives only sharp hypsochromic displacements of the maximum. The curves of (XV) and (XVI) do not intersect even at 100% pyridine (Fig. 7).

(XV)

(XVI)
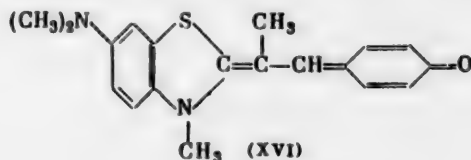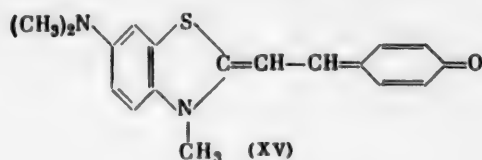
We also synthesized lower vinylene homologs of the anhydro bases (I) and (VII), preparations (XX) and (XXI), and also two vinylene homologs containing an anthraquinone nucleus, (XXII) and (XXIII) (see Table 3 for structural formulas). While there is apparently no steric hindrance interfering with the coplanarity of the nuclei in prepara-
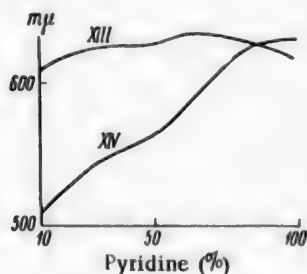
Fig. 6
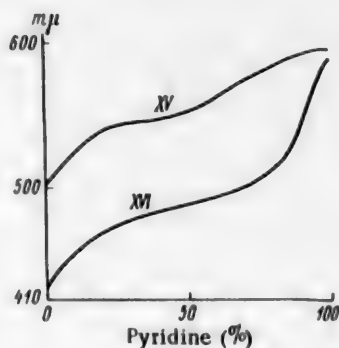
Fig. 7

tions (I, VII, and XXIII), which contain a dimethyne chain without substituents between the nuclei, such steric hindrance is possible in preparations (XX) and (XXI) and especially (XXII). Table 3 gives the absorption maxima and, in brackets, the corresponding molecular extinctions ($\epsilon \cdot 10^{-5}$) of the anhydro bases (XX, XXI, and XXII) and also, for comparison, those of their vinylene homologs (I, VII, and XXIII) in methanol, acetone, chloroform, benzene, and in methanol with hydrochloric acid added.

From the values of the molecular extinctions of the preparations (XX) and (XXI) it may be concluded that there is no substantial disruption of the coplanarity of the nuclei in these molecules. These extinctions are of the same order as those of their vinylene homologs (I) and (VII). For the latter, the extinctions are approximately twice as great as normal values for a longer chain. However, the molecular extinction of compound (XXII) in all solvents is a factor of approximately 5 lower than that of its vinylene homolog (XXIII). This shows that the benzthiazole and anthraquinone nuclei are not coplanar in the molecule of (XXII). It is noteworthy that the absorption maxima of preparation (XXII) in methanol, acetone, and chloroform lie at longer wavelengths than the corresponding absorption maxima of its vinylene homolog (XXIII). This may be explained only by the fact that in the molecule of the preparation (XXII), the anthraquinone nucleus is rotated about the double bond connecting it to the benzthiazole nucleus by a considerable angle.

TABLE 4

No. of corresponding anhydro base	Starting quaternary salt	Hydroxy carbonyl compound	Fusion time (hr)	Anion of salt obtained	Recrystallization solvent	Yield (%)	Melting point	Found (%)		Empirical formula	Calculated (%)
(I)	A	J	0.5	ClO_4*	Ethanol	65	267°	Cl 9.85,	9.86	$C_{16}H_{14}O_5NSCl$	9.66
(II)	B	J	3	ClO_4	Ethanol	48	181	Cl 9.34,	9.24	$C_{17}H_{16}O_5NSCl$	9.32
(III)	A	K	4	I**	Ethanol	11	249	I 30.31,	30.43	$C_{17}H_{16}ONSI$	31.04
(IV)	G	J	0.5	CH_3SO_4*	Water	85	280	S 8.68,	8.71	$C_{19}H_{19}O_5NS$	8.58
(V)	H	J	6	ClO_4	Methanol	45	215	Cl 9.38,	9.33	$C_{19}H_{18}O_5NCl$	9.46
(VI)	G	K	4	ClO_4	Water	6.4	210	Cl 9.48,	9.49	$C_{19}H_{18}O_5NCl$	9.46
(VII)	A	L	3	ClO_4***	Nitromethane	26	264	Cl 8.22,	8.19	$C_{20}H_{16}O_5NSCl$	8.50
(VIII)	B	L	5	ClO_4	Ethanol	40	214	Cl 8.30,	8.31	$C_{21}H_{18}O_5NSCl$	8.22
(IX)	C	J	0.2	ClO_4	Nitromethane	52	331	Cl 9.01,	9.03	$C_{16}H_{13}O_7N_2SCl$	8.60
(X)	D	J	4	ClO_4	Ethanol	41	266	Cl 8.34,	8.29	$C_{17}H_{15}O_7N_2SCl$	8.32
(XI)	C	L	0.2	ClO_4	Methanol	41	311	Cl 7.35,	7.28	$C_{20}H_{15}O_7N_2SCl$	7.67
(XII)	D	L	3	ClO_4	Ethanol + nitromethane	14	271	Cl 7.73,	7.81	$C_{21}H_{17}O_7N_2SCl$	7.46
(XIII)	E	L	4	I	–	70	278	I 26.01,	26.00	$C_{22}H_{21}ON_2SI$	25.97
(XIV)	F	L	10	ClO_4	Methanol	17	244	Cl 7.32,	7.30	$C_{23}H_{23}O_5N_2SCl$	7.48
(XV)	E	J	4	I	Methanol	34	283	I 29.30,	29.07	$C_{18}H_{19}ON_2SI$	29.16
(XVI)	F	J	8	ClO_4	Acetone	35	224	Cl 8.20,	8.29	$C_{19}H_{21}O_5N_2SCl$	8.36

* A. I. Kiprianov and V. E. Petrun'kin [1] described the ethiodide.

** The ethiodide has been described in the literature [9].

*** The anhydro base (VII) was described in [10].

The hydrochloride of compound (XXIII) is deeply colored in methanol and is hydrolyzed readily. On the other hand, preparation (XXII) is a strong base, giving stable salts. The fact that the absorption maximum of its hydrochloride (XXIV) lies in the comparatively short-wave region shows that the anthracene nucleus is rotated by a large angle about the single bond which connects it to the benzthiazole nucleus.
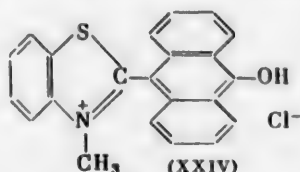
EXPERIMENTAL

Optical measurements. All measurements of the absorption curves were made with an SF-2M recording spectrophotometer. As the anhydro bases of the hydroxystyryls were unstable, especially if there was steric hindrance in their molecules, they were not isolated from the quaternary salts of the corresponding p-hydroxystyryls in a pure state. Their absorption spectra were measured in the following way. If it was necessary to determine not only the absorption maximum, but also the molecular extinction, a sample of the quaternary salt of the hydroxystyryl was dissolved in a definite volume of methanol in a graduated flask. Samples (1 ml) of this stock methanol solution were transferred to 10 ml graduated flasks with a pipette. The solvent was evaporated in vacuum at room temperature. The dry residue was dissolved in the appropriate solvent and the solution diluted to the mark. Immediately before the measurement, 1 drop of triethylamine was added to the solution of the hydroxystyryl salt. The time from the addition of the triethylamine to the end of the measurement was not more than 5 min. As many anhydro bases were decolorized appreciably even in this time, most measurements were made to determine only the absorption maximum with solutions of unknown concentration.

For the measurement of absorption maxima of anhydro bases in mixtures of pyridine and water, mixtures of 10 ml of water with 90 ml of pyridine, 20 ml of water with 80 ml of pyridine, etc. were prepared beforehand. The corresponding quaternary salt of the hydroxystyryl was dissolved in these mixtures. In most cases, triethylamine (1 drop to 10 ml) was added to the mixture immediately before the measurement.

The quaternary salts of the hydroxystyryls were obtained by mixing quaternary salts of nitrogen heterocycles containing a methyl or ethyl group in position 2 with p-hydroxybenzaldehyde (denoted by the letter J in Table 4), p-hydroxyacetophenone (K), or 1-hydroxy-4-naphthaldehyde (L). The following salts of nitrogen heterocycles were used: methylmethosulfate of 2-methylbenzthiazole (A), methylmethosulfate of 2-ethylbenzthiazole (B), methylmethosulfate of 2-methyl-6-nitrobenzthiazole (C), methylmethosulfate of 2-ethyl-6-nitrobenzthiazole (D), methiodide of 2-methyl-6- dimethylaminobenzthiazole (E), methiodide of 2-ethyl-6-dimethylaminobenzthiazole (F), methylmethosulfate of quinaldine (G), and the methylmethosulfate of 2-ethylquinoline (H). The quaternary salt and hydroxy carbonyl derivative were taken in equimolar amounts, usually 0.005 mole of each. Fusion at 140-150° was used for A, B, C, D, and E, and at 170-180° for F, G, and H. The melt obtained was dissolved in water and to the hot solution was added sodium iodide or perchlorate solution. When the mixture had cooled, the precipitate was collected and recrystallized from an appropriate solvent.

The conditions for the preparation of the quaternary salts of the hydroxystyryls and their yields, melting points, and analyses are given in Table 4.

2-(p-Hydroxyphenyl)-benzthiazole. A mixture of 5 g of o-aminophenyl mercaptan and 4.88 g of p-hydroxybenzaldehyde was fused at 100-110° until the evolution of water ceased. The solid product was recrystallized from 50% alcohol. The yield was 3.8 g (42%) and the m.p. 228-229° (literature data [11]: m.p. 228.6-229°).

The methiodide was obtained by boiling a solution of 1.14 g of the base and 0.75 g of dimethyl sulfate in 5 ml of xylene for 30 min. The precipitate was dissolved in hot water and sodium iodide added to the solution. Recrystallization from water gave 1.45 g (78%) of the salt. The light yellow crystals had m.p. 218°.

Found %: I 34.35, 34.16. $C_{14}H_{12}ONSI$. Calculated %: I 34.41.

2-(4'-Hydroxynaphthyl-1')-benzthiazole. A mixture of 1.25 g of o-aminophenyl mercaptan and 1.72 g of 1-hydroxy-4-naphthaldehyde was fused at 110-120° for 3 hr. The dark melt was recrystallized from toluene. We obtained 0.93 g (41%) of the product with m.p. 215°.

Found %: S 11.42, 11.25. $C_{17}H_{14}ONS$. Calculated %: S 11.55.

The methiodide was obtained by boiling a mixture of 0.93 g of the base and 0.5 g of dimethyl sulfate in 4 ml of xylene for 3 hr. The product was treated with sodium iodide and the iodide recrystallized from methanol. The dark yellow prisms had m.p. 260°. The yield was 0.9 g (64%).

Found %: I 29.56, 29.51. $C_{18}H_{14}ONSI$. Calculated %: I 30.31.

(3-Methylbenzthiazolinylidene-2)-9'-anthrone (XXII). A mixture of 1.45 g of the methylmethosulfate of 2-methylmercaptobenzthiazole and 0.97 g of anthrone in 10 ml of pyridine was boiled for 4 hr. The precipitate was collected and recrystallized twice from methanol. We obtained 0.75 g (44%) of dark green needles with m.p. 235°.

Found %: S 9.27, 9.38. $C_{22}H_{15}ONS$. Calculated %: S 9.38.

3-Methyl-2-formylmethylenebenzthiazoline. A mixture of 50 g of the methiodide of 2-β-anilidovinyl-benzthiazole, 21 g of potassium hydroxide, 300 ml of water, and 200 ml of n-propanol was boiled for 15 min and then steam distilled until the distillation of aniline ceased. The residue was cooled, separated from water, and dissolved in 200 ml of benzene, the solution filtered, and the filtrate evaporated to dryness in vacuum. The viscous red-brown mass obtained was recrystallized twice from ligroin. We obtained 6 g (60%) of light yellow needles with m.p. 97.5°. The substance has been described in the literature [12] as a noncrystalline mass.

Found %: S 16.72, 16.75. $C_{10}H_9ONS$. Calculated %: S 16.75.

[(3-Methylbenzthiazolylidene-2)-ethylidene]-9'-anthrone (XXIII). A mixture of 1.91 g of the previous compound and 1.94 g of anthrone was fused at 130° for 10 hr. The dye was extracted from the melt with 60 ml of boiling benzene. For removal of the unreacted starting materials, the benzene solution was shaken with hydrochloric acid until its color disappeared. The precipitated dark-blue tarry salt was washed twice with benzene and dissolved in methanol. The dye was precipitated from the methanol solution with ammonia and recrystallized twice from n-butanol. We obtained 0.45 g (12%) of fine dark green needles with m.p. 196°.

Found %: S 8.84, 8.86. $C_{24}H_{17}ONS$. Calculated %: S 8.69.

SUMMARY

The introduction of a methyl group into the α- or β-position of the chain in the molecule of the anhydro base of a hydroxystyryl derivative of benzthiazole or quinoline creates steric hindrance, which produces rotation of the heterocyclic (or benzene) nucleus. The order of the bond about which the nucleus rotates changes in solvents of different polarizing power. In accordance with this, the introduction of a methyl group produces a displacement of the absorption maximum toward shorter wavelengths (rotation of the nucleus about a predominantly single bond) or toward longer wavelengths (rotation of the nucleus about a predominantly double bond).

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CYANINE DYES WITH UNSATURATED SUBSTITUENTS

VIII. CIS-TRANS ISOMERISM OF THIACARBOCYANINES WITH STYRYL SUBSTITUENTS IN THE BENZTHIAZOLE NUCLEI

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The reaction of aromatic diazo compounds with α, β-unsaturated acids under the conditions of the Meerwein reaction [1] should lead to the formation of two geometric forms of the arylation products:

$$R-CH{=}CH-COOH + Ar-N_2^+Cl^- \rightarrow N_2 + CO_2 + HCl +$$

$$+ \quad \begin{matrix} H-C-R \\ \| \\ Ar-C-H \end{matrix} \quad \text{and} \quad \begin{matrix} H-C-R \\ \| \\ H-C-Ar \end{matrix}$$
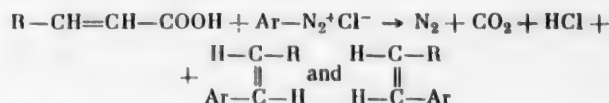
However, there have been hardly any reports in the literature on the isolation of cis- and trans-isomers in such cases. Only Brunner and Kustatscher [2] showed in 1951 that styrene is arylated by benzenediazonium chloride under the conditions of the Meerwein reaction to form a mixture of cis- and trans-stilbenes.

We observed that the reaction of 2-methyl-5- and 2-methyl-6-benzthiazolediazonium chlorides with cinnamic acid formed light yellow oils in addition to crystalline arylation products [3]. It was surmised that they contained the corresponding cis-isomers of 2-methyl-5- and 2-methyl-6-styrylbenzthiazoles. It seemed interesting to determine whether cis-isomers were actually formed in our case, to isolate them in a pure form, to study the possibility of interconversions of the cis- and trans-isomers, and also to synthesize cyanine dyes from them to determine the effect of the steric configuration on the color.

It is well-known that cis- and trans-isomers may be separated chromatographically [4-6]. This separation is based on the difference in the dipole moments of the geometric forms [7].

We also used chromatography to separate the supposed mixture of isomers. The crystals were first separated roughly by washing out the oil from them with alcohol or ether. After removal of the solvent, the residual oil, which still contained a small amount of the crystalline base, was dissolved in benzene and chromatographed on alumina. Benzene was used for elution. It was difficult to follow the separation during the passage of the mixture of substances through the column and so the solution draining from the column was divided into a series of fractions. After removal of the solvent it was found that the first fraction contained a mixture of crystals with a light yellow oil, in the next fractions the amount of crystals decreased, then oil without crystals was desorbed from the column, and finally, in the last fraction we found very small amounts of substances with m.p. 210-213° and 223-225° (for the 6- and 5-styryl derivatives, respectively), whose structures will be considered later. It was found that the elementary analyses of the fractions obtained agreed quite well with each other and with the analyses of the crystalline 2-methyl-5- and 2-methyl-6-styrylbenzthiazoles.

The degree of separation was determined from the ultraviolet absorption spectra of the chromatography fractions. This determination was based on the fact that the main absorption band (K-band) of cis-isomers generally has a lower extinction and coincides or is sometimes displaced somewhat toward shorter wavelengths in comparison with the K-band of trans-isomers [8].

In the chromatographic separation of the supposed mixture of geometric isomers of 2-methyl-6-styrylbenzthiazole, as a result of gradual enrichment of the fractions obtained in the oily product there was a gradual fall

In the extinction of the K-band on the corresponding absorption curves (Fig. 1) until it reached a practically constant value that was unchanged by further chromatography (see curves 4 and 5. Fig. 1). There was a similar change in the absorption curves during chromatography of the corresponding 5-styryl derivatives.

The light yellow oil obtained, which corresponded to the absorption curves with the lowest extinctions of the K-band (curves 4 and 5, Fig. 1), turned to a solid mass on standing. By reprecipitation with ammonia from hydrochloric acid solution, these bases were obtained in the crystalline state; the 5-styryl derivative had m.p. 68-70°,
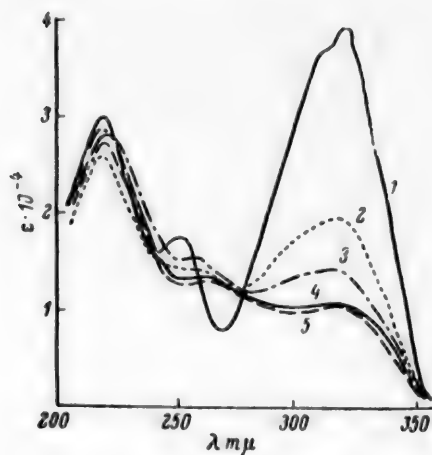
Fig. 1. Absorption spectra. 1) Trans-2-methyl-6-styrylbenzthiazole; 2-5) chromatography fractions with different contents of cis-2-methyl-6-styrylbenzthiazole.

Fig. 3. Absorption spectra. 1) Dimer; 2) cis-2-methyl-6-styrylbenzthiazole; 3) product obtained by heating dimer.
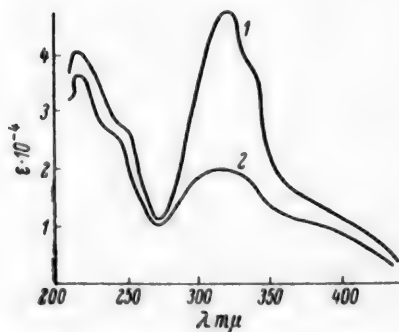
Fig. 2. Absorption spectra. 1) Picrate of 2-methyl-6-styrylbenzthiazole with m.p. 178-179°; 2) Picrate of 2-methyl-6-styryl-benzthiazole with m.p. 97-99°.

while the corresponding 6-styryl derivative melted over a wide range, indicating the presence of impurities. The picrates were prepared from the bases and in the case of 2-methyl-6-styrylbenzthiazole, we carried out fractional precipitation of the picrate and fractional crystallization of the fractions obtained from isopropanol. After purification, the picrate of 2-methyl-5-styrylbenzthiazole had m.p. 105-107° (the melting point of the picrate of the corresponding high-melting base was 198-199°) and the picrate of the 6-styryl derivative melted at 97-99° (the picrate of the supposed trans-isomer melted at 178-179°). The intensity of the main absorption band in the case of the picrates was also lower for the low-melting compounds than for the high-melting compounds (Fig. 2).

The picrate of 2-methyl-6-styrylbenzthiazole (m.p. 97-99°) was heated with sodium carbonate solution to give the base, which had m.p. 56-57° after reprecipitation from hydrochloric acid with ammonia. The analyses of the bases obtained corresponded to the same empirical formula as 2-methyl-5- and 2-methyl-6-styrylbenzthiazoles with m.p. 138-139° and 118°.

The data presented give adequate grounds for assuming that there is cis-trans isomerism in the products from the reaction of cinnamic acid with 2-methyl-5- and 2-methyl-6-benzthiazolediazonium chlorides, and that the isomers may be separated in a pure state.

It was important to determine whether cis-2-methyl-5- and 2-methyl-6-styrylbenzthiazoles were isomerized under the action of various chemical and physical agents and also under various storage conditions.

Measurement of the absorption spectrum of the cis-isomer of 2-methyl-6-styrylbenzthiazole after it had been kept on alumina for 2 days showed that there was no isomerization during chromatography. No isomerization occurred either when the cis-isomer was kept for 3 months in the dark. Likewise, boiling cis-2-methyl-6-styrylbenzthiazole in hydrochloric acid and in alcohol in the presence of iodine did not lead to the formation of the trans-isomer. Consequently, the cis-form of 2-methyl-6-styrylbenzthiazole is quite a stable compound. This conclusion was confirmed by the results of an investigation of the thermal stability of the cis-isomer; the trans-isomer could not be detected after the cis-isomer had been heated at 100, 150, and 250° for 1 hr with subsequent chromatography.
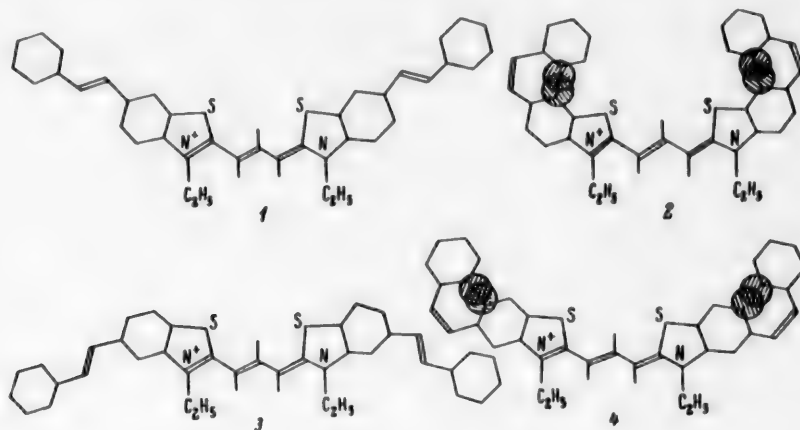
Fig. 4. Steric configurations: 1) Trans-3,3'-diethyl-6,6'-distyrylthiacarbocyanine; 2) cis-3,3'-diethyl-6,6'-distyrylthiacarbocyanine; 3) trans-3,3'-diethyl-5,5'-distyrylthiacarbocyanine; 4) cis-3,3'-diethyl-5,5'-distyrylthiacarbocyanine.

Cis-2-methyl-6-styrylbenzthiazole was irradiated in benzene with a mercury lamp for 15 hr and then the solution chromatographed on alumina. The formation of the trans-isomer was detected and in addition we isolated a product with m.p. 210-213°, which did not depress the melting point of the high-melting substance obtained during the chromatographic purification of cis-2-methyl-6-styrylbenzthiazole, obtained by the reaction of cinnamic acid with benzthiazolediazonium chloride. Judging by the elementary analysis and the molecular weight, the product with m.p. 210-213° was the dimer of 2-methyl-6-styrylbenzthiazole. As figure 3 shows, its absorption curve does not have a K-band, which is produced by an unsaturated grouping. It is interesting that on brief heating to 350° it was converted completely into cis-2-methyl-6-styrylbenzthiazole (curve 3. Fig. 3).

The data presented indicate that during irradiation, cis-2-methyl-6-styrylbenzthiazole is dimerized to form a cyclobutane derivative. The fact that thermal decomposition of the dimer formed only 2-methyl-6-styryl-benzthiazole indicates that the two monomer molecules added in the α, β'- and β, α'-positions with the formation of compound (I).
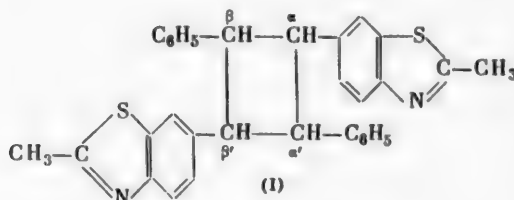
Had there been the formation of bonds between the α,α'- and β,β'-carbon atoms, decomposition of the cyclobutane ring should have yielded stilbene and 1,2-di-[2'-methylbenzthiazolyl-(6')]-ethylene together with 2-methyl-6-styrylbenzthiazole.

The reverse conversion of the trans-isomer into the cis-isomer was possible with irradiation in ultraviolet light. We irradiated a benzene solution of trans-2-methyl-6-styrylbenzthiazole with a mercury lamp for 100 hr; 40% of the trans-isomer was converted into the cis-form and 20% into the dimer. By thermal treatment, this dimer was also converted into cis-2-methyl-6-styrylbenzthiazole. This is a demonstration of the fact that only the cis-isomer of 2-methyl-6-styrylbenzthiazole is apparently capable of dimerization during irradiation.

It seemed of considerable interest to study the effect of the steric position of the styryl groups on the optical properties of distyrylthiacarbocyanines. If steric models of the dyes containing styryl groups in the cis- and trans-configurations are constructed, then as figure 4 shows, in the case of thiacarbocyanines with the styryl groups in the
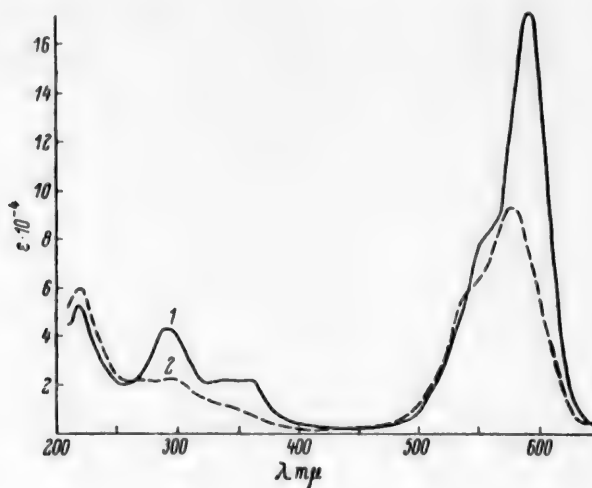
Fig. 5. Absorption spectra. 1) 3,3'-Diethyl-6,6'-di(trans-styryl)-thiacarbocyanine; 2) 3,3'-diethyl-6,6'-di(cis-styryl)-thiacarbo-cyanine.

cis-position there arises steric hindrance to their lying in the same plans as the dye molecule as a whole, while this hindrance does not occur when these substituents have a trans-configuration. It is known that one condition for electronic displacements along conjugation chains, characteristic of any dye, is that the chromophoric system, including the aromatic and heterocyclic nuclei, should lie in one plane. If the coplanarity of parts of the dye molecule is disrupted in any way, then this is reflected first of all in its color and absorption intensity [9]. The introduction into the molecule of a symmetrical cyanine dye of bulky substituents which upset the planarity of the structure of the main polymethyne chromophore leads to a displacement of the absorption band toward longer wavelengths [10].

On the other hand, a whole series of papers have been published [11-13] showing that the introduction into the heterocyclic groups of cyanines of additional substituents,creating hindrance to the auxochromic groups already present lying in the plane of the molecule, produces a hypsochromic effect.

In all the cases presented, in addition to the steric effects of the substituents, their electronic character may also have a definite effect on the color. This type of complication may be avoided by comparing the absorption spectra of dyes containing cis- and trans-styryl radicals in benzthiazole nuclei,as they contain the same groups, differing only in steric configuration. For this purpose, we treated cis-2-methyl-5- and 2-methyl-6-styrylbenzthiazoles with diethyl sulfate to obtain the quaternary salts, from which we prepared thiacarbocyanines, which were more highly colored and had lower absorption intensities both in the visible and ultraviolet regions than the corresponding dyes containing trans-styryl groups (see table and Figs. 5 and 6).
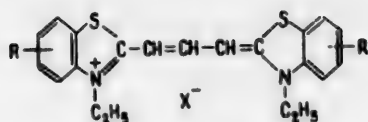
R	5,5'-Derivatives		6,6'-Derivatives	
	λ_{max} (mμ)	$\varepsilon_{max} \cdot 10^4$	λ_{max} (mμ)	$\varepsilon_{max} \cdot 10^4$
Trans- ⬡ —CH=CH—	578	17.6	595	17.4
Cis- ⬡ —CH=CH—	574	10.2	579	9.3

This indicates that the conjugation of the styryl groups with the main polymethyne chromophore in the cis-distyrylthiacarbocyanines is hindered.

It is interesting that the hypsochromic displacement observed with a change from the trans- to the cis-isomer was much greater with the 6,6'-derivatives than with the 5,5'-derivatives.
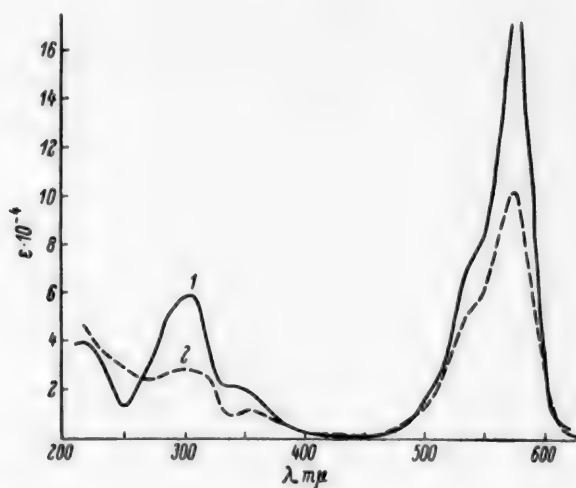
Fig. 6. Absorption spectra. 1) 3,3'-Diethyl-5,5'-di(trans-styryl)-thiacarbocyanine; 2) 3,3'-diethyl-5,5'-di(cis-styryl)-thiacarbocyanine.

It is not quite clear why the extinction of the main band of the cis-distyryl derivatives is lower than that of the corresponding trans-isomers,as until now it has been considered that the absorption intensity in the case of symmetrical cyanines is reduced by disruption of the coplanarity of the main chromophore system.

It should be noted that after the carbocyanine condensation of the ethylethosulfates of 2-methyl-5-cis- and 2-methyl-6-cis-styrylbenzthiazoles in the reaction mixtures we could not detect dyes with absorption maxima characteristic of the corresponding trans-distyrylthiacarbocyanines. This demonstrates that there was no isomerization of the cis-form to the trans-form either during the preparation of the quaternary salts or during the formation of the dyes.

We also prepared an unsymmetrical dye from the dimer of 2-methyl-6-styrylbenzthiazole with the structure (II) by the reaction of the diquaternary salt of the dimer with the ethylmethosulfate of 2-β methylmercaptovinyl-benzthiazole in anhydrous alcohol in the presence of triethylamine.

(II)
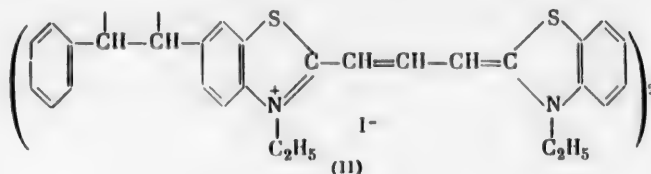
Its absorption curve, which is given in figure 7, showed two absorption maxima: one at 565 mμ and a less intense maximum at 528 mμ. The position of the longwave absorption maximum indicates that there was no conjugation between the two parts of the complex dye molecule; the nature of the absorption band at 528 mμ remains obscure.

EXPERIMENTAL

<u>Cis- and trans-2-methyl-6-styrylbenzthiazoles.</u> The reaction of 16.4 g of diazotized 2-methyl-6-aminobenzthiazole with 14.8 g of cinnamic acid under the conditions of the Meerwein reaction and subsequent purification of the reaction mixture yielded a thick yellow oil, which partly crystallized [3]. The weight was 8.37 g (33.3%). To the mixture of oil and crystals was added ether and the crystals collected. The yield was 5.67 g (22.6%) and the m.p. 112-115°. Recrystallization from alcohol yielded 4.6 g (18.4%) of trans-2-methyl-6-stryl-benzthiazole. The light yellow platelets with a pearly luster had m.p. 118°. The picrate of trans-2-methyl-6-styrylbenzthiazole formed yellow crystals (from alcohol) with m.p. 178-179°.

Found %: S 13.11, 13.03; N 5.50, 5.76. $C_{16}H_{13}NS$. Calculated %: S 12.71; N 5.57.

Analysis of picrate. Found %: N 11.54, 11.42. $C_{22}H_{16}O_7N_4S$. Calculated %: N 11.67.

Fig. 7. Absorption curve of di-(6-styryl)-thiacarbocyanine.

Removal of the ether yielded 2.45 g of a light yellow oil. A 6.4 g sample of the oil was dissolved in benzene. The benzene solution was chromatographed on alumina (column diameter 27 mm, height of Al_2O_3 bed 40 cm). Benzene was used for elution. The eluate was arbitrarily divided into 5 fractions. After removal of the benzene from each fraction, samples were taken for measurement of the ultraviolet absorption curves. The 1st fraction consisted of 2.2 g of a mixture of oil and crystals (Fig. 8, curve 1) (0.4 g of crystals of the trans-isomer with m.p. 114-117° was washed out with ether). The 2nd fraction consisted of 1.27 g of a mixture of oil and crystals (Fig. 8, curve 2) (0.3 g of the trans-isomer with m.p. 110-113° was washed out with ether). The 3rd fraction was 1.49 g of oil with a small amount of crystals (Fig. 8, curve 3). The 4th fraction was 0.85 g of oil (Fig. 8, curve 4). The 5th fraction was 0.34 g of a thick oil (Fig. 8, curve 5). Solution of the 5th fraction in ether yielded 0.2 g of crystals with m.p. 210-213° (from alcohol). The 1st and 2nd fractions were combined, rechromatographed, and also divided into a series of fractions (Fig. 9).

Figure 10 gives the absorption curves of samples taken during the chromatography of the 3rd fraction. No change in the extinctions of the main band was observed with further chromatography of the fractions with the absorption curves 4 (Fig. 8), 2, 3 (Fig. 9), 2, and 3 (Fig. 10); consequently, the curves practically coincided. From the 5th fraction we also isolated a yellow oil with an analogous absorption curve. The total yield of the product with a constant absorption curve was 4.64 g, which corresponds to 7.1% calculated on the starting 2-methy-6-amino-benzthiazole. A 1.45 g sample of the light yellow oil (cis-2-methyl-6-styrylbenzthiazole, isolated by chromato-

graphy) was dissolved in 20 ml of alcohol. A solution of 1.35 g of picric acid in 20 ml of alcohol was divided into 4 portions and each portion added in turn to the hot alcohol solution of the cis-isomer, with the precipitated picrate fractions isolated separately. 1st fraction, 0.52 g, m.p. 85-95°; 2nd fraction, 0.55 g, m.p. 90-95°; 3rd fraction, 0.44 g, m.p. 90-95°; 4th fraction, 0.7 g, m.p. 90-95°. Repeated fractional crystallization of the portions of picrates obtained from isopropanol yielded yellow crystals with m.p. 97-99°.

Found %: N 11.32, 11.51. $C_{22}H_{16}O_7N_4S$. Calculated %: N 11.67.

The picrate of cis-2-methyl-6-styrylbenzthiazole was boiled with 10% sodium carbonate solution. The base was purified by chromatography and reprecipitation from hydrochloric acid with ammonia. This yielded a colorless powder of cis-2-methyl-6-styrylbenzthiazole with m.p. 55-57°.

Found %: N 5.72, 5.76; S 12.47, 12.76. $C_{16}H_{13}NS$. Calculated %: N 5.57; S 12.71.
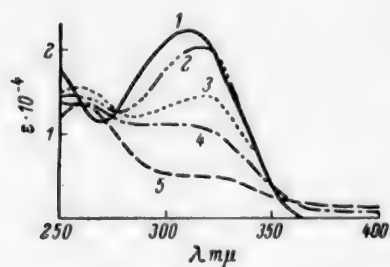
Fig. 8. Absorption curves of chromatographic fractions of the mixture of cis- and trans-2-methyl-6-styrylbenzthiazoles. Explanation in text.
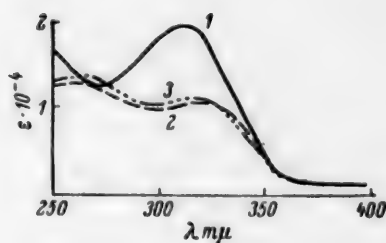
Fig. 9. Absorption curves of chromatographic fractions of 2-methyl-6-cis-styrylbenzthiazole and a mixture of cis- and trans-isomers. Explanation in text.

Irradiation of cis-2-methyl-6-styrylbenzthiazole with a mercury lamp. A solution of 0.5 g of cis-2-methyl-6-styrylbenzthiazole in 100 ml of benzene was irradiated with a mercury lamp for 15 hr, then evaporated to 30 ml and chromatographed on a column of alumina. Benzene was used for elution. Chromatography yielded 0.25 g of unchanged cis-2-methyl-6-styrylbenzthiazole, 0.07 g of the trans-isomer with m.p. 118°, and 0.16 g of a product with m.p. 201-204°, which had, after recrystallization from alcohol, m.p. 210-213°. The product did not depress the melting point of the substance isolated from the 5th fraction during the chromatographic purification of cis-2-methyl-6-styrylbenzthiazole (see previous experiment).

Found %: C 76.25; H 5.25; N 5.43, 5.26; S 12.75, 12.87. M 463.8, 428.9. $[C_{16}H_{13}NS]_2$. Calculated %: C 76.49; H 5.17; N 5.57; S 12.75. M 502.

A 0.3 g sample of the dimer of 2-methyl-6-styrylbenzthiazole was heated in a flask on Wood's alloy to 350°. The melt was dissolved in 20 ml of benzene. The benzene solution was chromatographed on alumina. The light yellow oil isolated after chromatography was dissolved in 30 ml of concentrated hydrochloric acid and the solution neutralized with aqueous ammonia solution. The crystalline precipitate was collected, washed with water, and dried (0.2 g). The product melted at 57-58° and did not depress the melting point of cis-2-methyl-6-styrylbenzthiazole.

Irradiation of trans-2-methyl-6-styrylbenzthiazole with a mercury lamp. A 5.4 g sample of trans-2-methyl-6-styrylbenzthiazole was dissolved in 100 ml of benzene. The solution was placed in a quartz beaker and irradiated with a mercury lamp with stirring for 100 hr. It was then evaporated to 40 ml and chromatographed on alumina. Benzene was used for elution. The eluate was divided into a series of fractions, which were rechromatographed. The degree of separation was determined by means of the ultraviolet absorption spectra of the fractions. Repeated chromatography yielded 2.25 g of unchanged trans-2-methyl-6-styrylbenzthiazole, 2.1 g of cis-2-methyl-6-styryl-benzthiazole, and 0.9 g of a product with m.p. 210-213°, which did not depress the melting point of the dimer of 2-methyl-6-styrylbenzthiazole. Heating this substance to 350° with subsequent chromatographic purification and reprecipitation from hydrochloric acid with ammonia yielded cis-2-methyl-6-styrylbenzthiazole with m.p. 57-58°. The trans-isomer was not detected.

Cis- and trans-2-methyl-5-styrylbenzthiazoles. A 16.4 g sample of diazotized 2-methyl-5-aminobenzthiazole was treated with 14.8 g of cinnamic acid under the conditions of the Meerwein reaction [3]. Chromatography of a chloroform solution of the product gave a thick yellow oil, which partly crystallized. The weight was 7.5 g. The base was recrystallized from 140 ml of methanol with the addition of animal charcoal. The yield of trans-2-methyl-5-styrylbenzthiazole was 5 g (20%). The light yellow crystals had m.p. 138-139° and were soluble in benzene, chloroform, and acetone, and more difficultly soluble in alcohol and ether.

The picrate formed fine yellow crystals with m.p. 198-199° (from alcohol).

Found %: S 12.52, 12.74. $C_{16}H_{13}NS$. Calculated %: S 12.71.

Analysis of picrate. Found %: N 11.73, 11.90. $C_{22}H_{16}O_7N_4S$. Calculated %: N 11.67.
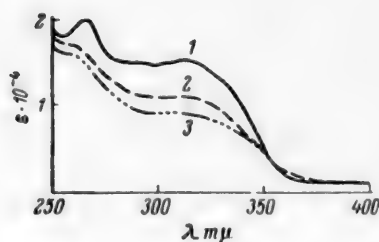
Fig. 10. Absorption curves of 2-methyl-6-cis-styrylbenzthiazole. Explanation in text.
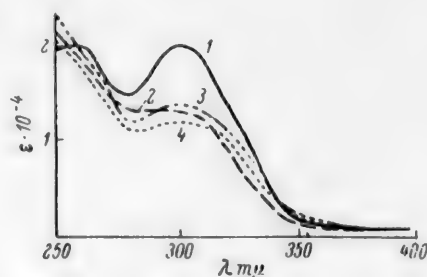
Fig. 11. Absorption curves of chromatographic fractions corresponding to different contents of 2-methyl-5-cis-styrylbenzthiazole. Explanation in text.

The mother solution after crystallization of the trans-isomer was evaporated in vacuum. The residue was 2.5 g of a light yellow oil, which was chromatographed on alumina as a benzene solution. Benzene was used for elution. The eluate was divided into 5 fractions. After removal of the benzene, a sample was taken from each fraction for measurement of the ultraviolet absorption curve (Fig. 11). The 1st fraction, 0.8 g of a mixture of oil and crystals (Fig. 11, curve 1), from which 0.22 g of crystals of the trans-isomer with m.p. 138-139° was washed out with ether. The 2nd fraction was 0.4 g of oil (Fig. 11, curve 2). The 3rd fraction was 0.4 g of oil (Fig. 11, curve 3). The 4th fraction was 0.67 g of oil (Fig. 11, curve 4). The 5th fraction was 0.15 g of crystals. Recrystallization of the latter from alcohol gave 0.1 g of a product with m.p. 223-225° (Fig. 11, curve 5).

The 2nd, 3rd, and 4th fractions were rechromatographed and also arbitrarily divided into a series of fractions, but in none of them could we detect crystals of the trans-isomer or the product with m.p. 223-225°. The ultraviolet absorption curves of these fractions coincided with each other and also with the absorption curves of the starting bases taken for chromatography (Fig. 11, curves 2-4).

A 0.5 g sample of the oily product was dissolved in 80 ml of dilute hydrochloric acid (1 : 1). The solution was neutralized with 90 ml of 10% ammonia solution with cooling. The precipitate of cis-2-methyl-5-styrylbenzthiazole was collected, washed with water, and dried. The weight was 0.45 g. The colorless powder had m.p. 68-70°.

The picrate of cis-2-methyl-5-styrylbenzthiazole formed yellow crystals (from isopropanol) with m.p. 105-107°.

Found %: N 5.59, 5.61; S 12.70, 12.64. $C_{16}H_{13}NS$. Calculated %: N 5.57; S 12.74.

Analysis of picrate. Found %: N 11.37, 11.18. $C_{22}H_{16}O_7N_4S$. Calculated %: N 11.67.

Quaternary Salts

Ethyl-p-toluenesulfonate of 2-methyl-trans-5-styrylbenzthiazole. A mixture of 5.02 g (0.02 mole) of 2-methyl-trans-5-styrylbenzthiazole and 8.8 g (0.044 mole) of ethyl p-toluenesulfonate was heated on an oil bath at 150-160° for 8 hr. The quaternary salt was dissolved in 250 ml of water and the aqueous solution washed with benzene, decolorized with charcoal, filtered, and evaporated on a water bath. The yield was 8.8 g (97.7%). The salt was used for the synthesis of the dye without further purification.

The bromoethylate of 2-methyl-trans-5-styrylbenzthiazole was prepared by the action of 30 ml of a hot 20% aqueous solution of potassium bromide on 1 g of the ethyl-p-toluenesulfonate of 2-methyl-5-styrylbenzthiazole in 45 ml of water. The precipitate was washed with water and alcohol and recrystallized from alcohol. The yield was 0.59 g (74.5%) of colorless prisms with m.p. 220°.

Found %: Br 21.98, 22.06. $C_{18}H_{18}NSBr$. Calculated %: Br 22.21.

Bromoethylate of 2-methy-cis-5-styrylbenzthiazole. A mixture of 0.25 g (0.001 mole) of 2-methyl-5-cis-styrylbenzthiazole and 0.16 g (0.00105) of diethyl sulfate was heated at 120° for 45 min. A solution of the quaternary salt in 3 ml of alcohol was treated with 20 ml of a hot 10% solution of potassium bromide. An oil precipitated and this solidified on standing for 2 days. The weight was 0.3 g. The precipitate was dissolved in 20 ml of alcohol and the quaternary salt precipitated with 100 ml of ether, collected, and dried in a desiccator. The yield was 0.15 g (41%) of a light yellow powder with m.p. 144-145°.

Found %: Br 22.13. $C_{18}H_{18}NSBr$. Calculated %: Br 22.21.

Ethyl-p-toluenesulfonate of 2-methyl-trans-6-styrylbenzthiazole. This salt was obtained analogously to the ethyl-p-toluenesulfonate of 2-methyl-5-styrylbenzthiazole from 2.51 g (0.01 mole) of 2-methyl-6-styrylbenzthiazole and 4 g (0.02 mole) of ethyl p-toluenesulfonate. The yield was 4.3 g (94%). The quaternary salt was used to prepare the dye without further purification.

The iodoethylate of 2-methyl-trans-6-styrylbenzthiazole was obtained by mixing a solution of 1 g (0.0022 mole) of the ethyl-p-toluenesulfonate of 2-methyl-6-styrylbenzthiazole in 30 ml of water with 30 ml of a hot 10% aqueous solution of potassium iodide. The iodoethylate was collected, washed with water and alcohol, and recrystallized from alcohol. The yield was 0.5 g (63.2%) of colorless silky needles with m.p. 205-207°.

Found %: I 31.25, 31.37. $C_{18}H_{18}NSI$. Calculated %: I 31.20.

Iodoethylate of 2-methyl-cis-6-styrylbenzthiazole. A mixture of 0.25 g (0.001 mole) of 2-methyl-6-cis-styrylbenzthiazole and 0.16 g (0.00105 mole) of diethyl sulfate was heated at 120°, the quaternary salt formed dissolved in 3 ml of alcohol, and the solution poured into 20 ml of a hot 10% solution of potassium iodide. On cooling, there formed an oil, which rapidly crystallized; the weight was 0.4 g and the m.p. 70-85°. The precipitate was dissolved in 20 ml of anhydrous alcohol and the quaternary salt precipitated with 100 ml of ether, collected, and dried in a vacuum desiccator. The yield was 0.2 g (49.2%) of a light yellow powder with m.p. 169°.

Found %: I 31.29, 31.34. $C_{18}H_{18}NSI$. Calculated %: I 31.20.

Dyes

3,3'-Diethyl-5,5'-di-trans-styrylthiacarbocyanine-p-toluenesulfonate and 3,3'-diethyl-6,6'-di-trans-styryl-thiacarbocyanine iodide were prepared by us previously [3].

3,3'-Diethyl-5,5'-di-cis-styrylthiacarbocyanine ethylsulfate. A mixture of 0.5 g (0.002 mole) of cis-2-methyl-5-styrylbenzthiazole and 0.32 ml (0.00210 mole) of diethyl sulfate was heated at 120° for 45 min. To the quaternary salt were added 0.59 g (0.004 mole) of ethyl orthoformate and 3 ml of pyridine. The mixture was heated at 120° for 1 hr and then the dye precipitated with ether. It weighed 0.9 g. Recrystallization from alcohol gave 0.28 g (40.6%) of dark violet crystals with m.p. 223-225°.

Found %: N 3.90, 4.06; S 13.80, 13.97. $C_{39}H_{38}O_4N_2S_3$. Calculated %: N 4.03; S 13.83.

A chloroform solution of a sample of the crude product (after precipitation from the reaction mixture with ether) was chromatographed on alumina. Elution with a 10% solution of alcohol in chloroform washed out only one band. The dyes obtained from a mixture of cis- and trans-2-methyl-5-styrylbenzthiazoles were separated into two bands by chromatography under analogous conditions. The upper band was the dye from the trans-isomer with an absorption maximum at 579 mμ.

3,3'-Diethyl-6,6'-di-cis-styrylthiacarbocyanine ethylsulfate. A mixture of 0.25 g (0.001 mole) of cis-2-methyl-6-styrylbenzthiazole and 0.16 g (0.00105 mole) of diethyl sulfate was heated at 120° for 30 min. To the quaternary salt were added 0.3 g (0.004 mole) of ethyl orthoformate and 3 ml of pyridine. The mixture was heated at 120° for 1 hr; it thereupon acquired a violet color. The dye was precipitated with ether. It weighed 0.4 g. When chromatographed on alumina, a sample of the dye in chloroform gave one band, while the thiacarbocyanines obtained from a mixture of cis- and trans-2-methyl-6-styrylthiacarbocyanine were separated on alumina, with the

trans-distyryl derivative (λ_{max} 595 mμ) desorbed with the greatest difficulty. Recrystallization from 30 ml of alcohol gave 0.06 g (17.4%) of dark violet crystals with m.p. 250-252°.

Found %: N 4.29, 4.32; S 13.67, 13.57. $C_{39}H_{38}O_4N_2S_3$. Calculated %: N 4.03; S 13.83.

Bis-[6-styrylthiacarbocyanine iodide]. A mixture of 0.25 g (0.0005 mole) of the dimer of 2-methyl-6-styryl-benzthiazole and 0.16 g (0.00125 mole) of diethyl sulfate was heated at 140° for 4 hr. The quaternary salt was dissolved in 3 ml of anhydrous alcohol and to the solution were added 0.36 g (0.001 mole) of the methylsulfate of 2-ß-mercaptovinylbenzthiazole and 0.42 ml (0.003 mole) of triethylamine. The mixture was heated on a boiling water bath for 15 min. The dye formed was precipitated with ether and dissolved in 20 ml of alcohol and the hot solution of the dye poured into 20 ml of a hot 10% aqueous solution of potassium iodide. On the following day the dye was collected and washed with water, alcohol, and ether. Two recrystallizations from alcohol gave 0.11 g (18.5%) of green crystals with m.p. 231-232°.

Found %: S 10.86, 10.83. $C_{29}H_{27}N_2S_2I$. Calculated %: S 10.77.

SUMMARY

1. With the examples of 2-methyl-5- and 2-methyl-6-styrylbenthiazoles it was shown that the reaction of benzthiazolediazonium chlorides with α, β-unsaturated acids forms a mixture of cis- and trans-isomers. Cis- and trans-2-methyl-5- and 2-methyl-6-styrylbenzthiazoles were separated chromatographically.

2. Irradiation of cis-2-methyl-6-styrylbenzthiazole with ultraviolet light formed the trans-isomer and the dimer of the base, which was again converted to the monomer by heating. Irradiation of the corresponding trans-isomer led to a mixture of the cis-isomer and its dimer.

3. It was shown that the cis-form was not isomerized to the trans-form either during the preparation of quaternary salts or during the formation of dyes from 2-methyl-styrylbenzthiazoles.

4. It was shown that di-cis-styrylthiacarbocyanines absorb light at a shorter wavelength than the corresponding trans-isomers. This indicates that conjugation of the styryl groups with the main chromophore is hindered in cis-distyryl derivatives.

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p-DI(2-CHLOROETHYL)-AMINOPHENYLALANINE(SARCOLYSIN) AND ITS DERIVATIVES

VI. AMIDES OF N-ACETYLSARCOLYSIN AND CERTAIN AMINES OF THE THIAZOLE SERIES

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Continuing our previous investigations [1], we synthesized a number of amides which are derivatives, on the one hand, of N-acetyl sarcolysin and, on the other, of certain amines containing the thiazole ring. By way of the latter compounds, we employed 2-aminomethyl thiazole (I), 4-aminomethyl thiazole (II), 2-methyl-4-aminomethyl thiazole (III) and 5-aminothiazole (IV).
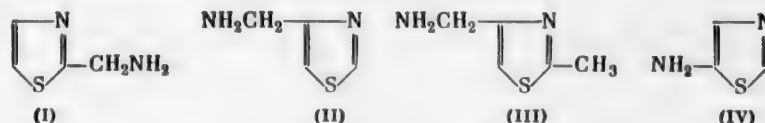
We used Gabriel's method [2] for synthesizing (I), (II), and (III). Hitherto, this method has hardly been used in the thiazole series. There is only one report [3] dealing with the synthesis of 4-β-phthalimidoethyl thiazole (with a poor yield) by the condensation of 4-β-chloroethyl thiazole with potassium phthalimide in decalin at 190°. We used somewhat different conditions: a mixture of potassium phthalimide and the corresponding chloromethyl thiazole compounds was heated without a solvent at 150-180°. For conversion to amines, the phthalimidomethyl thiazole compounds were boiled with hydrazine hydrate in alcoholic solution [4].

2-Aminomethyl thiazole (I) was synthesized as follows: thiazole was heated with 2-hydroxymethyl thiazole (V), which was then converted to 2-chloromethyl thiazole (VI). By condensation of the latter with potassium phthalimide we obtained 2-phthalimidomethyl thiazole (VII), which was hydrolyzed to (I) with a yield of 80%. This compound was previously obtained with a yield of 31% by another method [4].
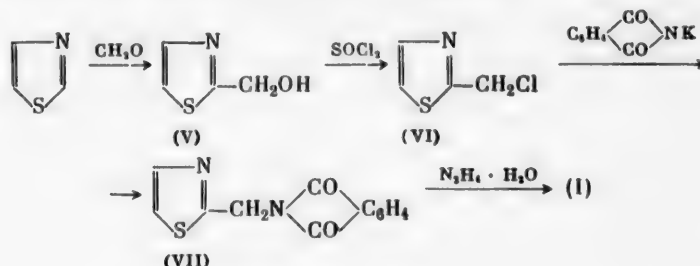
In a similar manner, 4-chloromethyl thiazole (VIII), obtained from its hydrochloride [5], was converted to 4-phthalimidomethyl thiazole (IX) and then to 4-aminomethyl thiazole (II). The hydrochloride of the latter had an m.p. of 212-213° (from anhydrous alcohol), whereas the literature [4] gives an m.p. of 183-185°. 2-Methyl-4-phthalimidomethyl thiazole (XI) was synthesized from 2-methyl-4-phthalimidomethyl thiazole (X) [6] and potassium phthalimide, and was then hydrolyzed to 2-methyl-4-aminomethyl thiazole (III).

TABLE 1. Phthalimidomethyl Thiazoles

Name	Empirical formula	Yield (%)	Melting point	Calculated (%)			Found (%)		
				C	H	N	C	H	N
2-Phthalimidomethyl thiazole (VII).	$C_{12}H_8O_2N_2S$	57.8	117—118°	59.01	3.28	—	58.88	3.43	—
4-Phthalimidomethyl thiazole (IX).	$C_{12}H_8O_2N_2S$	60	157—158° *	59.01	3.28	11.48	58.58	3.32	11.45
2-Methyl-4-phthalimidomethyl thiazole (XI).	$C_{13}H_{10}O_2N_2S$	63.5	146—146.5	60.46	3.87	10.85	60.48	4.04	10.85

TABLE 2. Aminomethyl Thiazoles

Name	Empirical formula	Yield (%)	Melting (boiling) point	Calculated (%)			Found (%)			Note
				C	H	Cl	C	H	Cl	
2-Aminomethyl thiazole hydrochloride (hydrochloride of I).	$C_4H_7N_2SCl$	—	186-187° [From anhydrous alcohol]	31.89	4.65	23.59	31.96	4.54	23.50	Base: yield 80%, b.p. 93-95° (14 mm).
4-Aminomethyl thiazole hydrochloride (hydrochloride of II).	$C_4H_7N_2SCl$	69.5 (Base)	212-213°** [From anhydrous alcohol]	31.89	4.65	23.59	32.26	4.45	23.32	Obtained by passing dry HCl into a solution of (II) in absolute ether.
2-Methyl-4-aminomethyl thiazole (III).	$C_5H_8N_2S$	86	B.p. 106-107° (22 mm)	46.89	6.25	—	46.96	6.18	—	n_D^{20} 1.553

* M.p. 156-157° [4].
** M.p. 183-185° [4].

TABLE 3. Thiazolyl Amides of N-Acetyl Sarcolysin

Name of the amide of N-acetyl Sarcolysin	Empirical formula	Yield (%)	Melting point	Calculated (%)				Found (%)			
				C	H	N	Cl	C	H	N	Cl
(2-Thiazolyl-methyl)-amide (XV)	$C_{19}H_{24}O_2N_4SCl_2$	80	174.5—175.5°	51.47	5.42	—	16.03	51.45	5.53	—	15.72
(4-Thiazolyl-methyl)-amide (XVI)	$C_{19}H_{24}O_2N_4SCl_2$	73	160—161°	51.47	5.42	12.64	16.03	51.39	5.53	12.23	15.51
(2-Methyl-4-thiazolyl-methyl)-amide (XVII)	$C_{20}H_{26}O_2N_4SCl_2$	85.8	141—142°	52.51	5.68	—	15.85	52.47	5.61	—	15.79
Thiazolyl-5-amide (XVIII)	$C_{18}H_{22}O_2N_4SCl_2$	23.3	210—211°	50.35	5.13	13.05	16.55	50.19	5.20	12.45	15.88

$ClCH_2$—[thiazole]—N $\rightarrow$ $C_6H_4\langle\begin{smallmatrix}CO\\CO\end{smallmatrix}\rangle NCH_2$—[thiazole]—N $\rightarrow$ (II)

(VIII)   (IX)

$ClCH_2$—[thiazole]—N, —CH_3 $\rightarrow$ $C_6H_4\langle\begin{smallmatrix}CO\\CO\end{smallmatrix}\rangle NCH_2$—[thiazole]—N, —$CH_3$ $\rightarrow$ (III)

(X)   (XI)
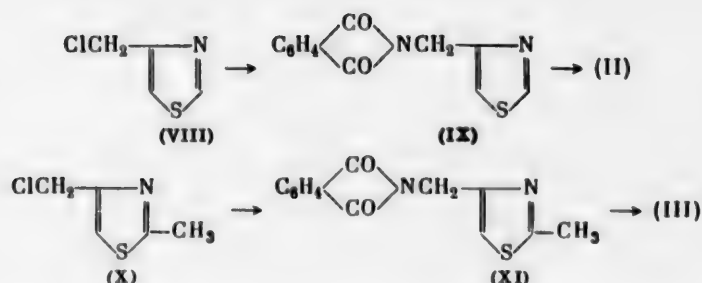
The properties and analyses of the phtalimidomethyl thiazoles and aminomethyl thiazoles we obtained are given in Tables 1 and 2 respectively.

We made attempts to obtain 5-aminomethyl thiazole in the same way. From 5-hydroxymethyl thiazole [7] we obtained its hydrochloride (XII), which by reacting with excess thionyl chloride was converted to 5-chloromethyl thiazole (XIII), isolated as the picrate. We were unable to purify the base obtained by decomposing the picrate because it dissociated when distilled under vacuum. This thermal instability of the substance was evidently the cause of the fact that attempts to condense unpurified 5-chloromethyl thiazole with potassium phthalimide, which generally requires fairly vigorous heating, did not give the desired 5-phthalimidomethyl thiazole.

$OHCH_2$—[thiazole]—N $\rightarrow$ $OHCH_2$—[thiazole]—N·HCl $\rightarrow$ $ClCH_2$—[thiazole]—N

(XII)   (XIII)
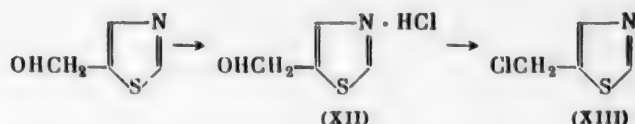
By reacting N-acetyl sarcolysin (XIV) with aminomethyl thiazoles (I), (II) and (III), and with 5-aminothiazole (IV) [8] in the presence of dicyclohexylcarbodiimide in chloroform by a previously described method [1], the following compounds were synthesized, respectively: 2 thiazolyl methylamide (XV), (4-thiazolyl methyl)-amide (XVI), (2-methyl-4-thiazolyl methyl)-amide (XVII) and (thiazolyl-5)-amide (XVIII) of N-acetyl sarcolysin. The properties and analyses of the amides obtained are given in Table 3.

$\begin{matrix}ClCH_2CH_2\\ClCH_2CH_2\end{matrix}$N—⟨benzene⟩—$CH_2CHCOOH$ + NH_2R $\rightarrow$
                       |
                     $NHCOCH_3$

(XIV)   (I–IV)

$\rightarrow$ $(ClCH_2CH_2)_2$N—⟨benzene⟩—CH_2CHCO—NHR
                            |
                      $NHCOCH_3$

(XV–XVIII)

(XV) R = [thiazol-2-yl]—CH_3—,   (XVI) R = [4-thiazolyl with —CH_3],   (XVII) R = [thiazolyl with —CH_3 and S—CH_3]

(XVIII) R = [thiazol-5-yl]
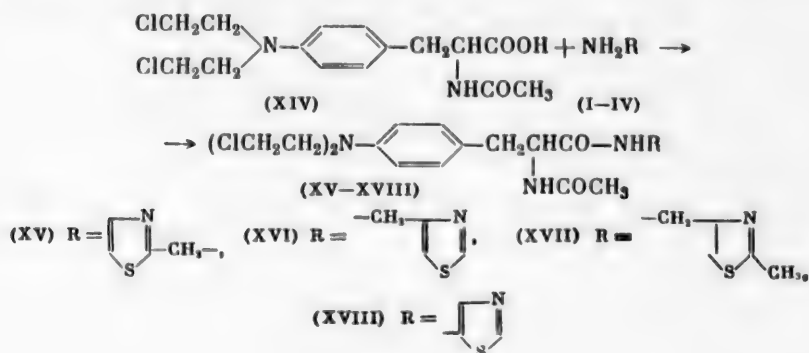
EXPERIMENTAL

2-Hydroxymethyl thiazole (V). A mixture of 8.5 g of thiazole (b.p. 116-117°) in 25 ml of 40% formalin was heated in a test-tube autoclave at 120° (bath temperature) for 6 hours. The cooled reaction mixture was acidified with dilute hydrochloric acid and the neutral admixtures were extracted with ether. The aqueous layer was neutralized and acidified(solid potash). The oil which separated out was extracted with ether, the extract was dried with anhydrous sodium sulfate, the ether and the unreacted thiazole (2.9 g) were distilled and the residue was treated with dilute (1 : 1) hydrochloric acid and then evaporated under vacuum. When the oily residue was shaken with anhydrous alcohol it crystallized out. We obtained 2.33 g (22.5% calculated on the reacted thiazole) of 2-hydroxy-

methyl thiazole hydrochloride (m.p. 121-125°). After recrystallization from anhydrous alcohol the substance melted at 126.5-127°.

Found %: C 32.00; H 3.93; N 8.89; Cl 22.58. C_4H_6ONSCl. Calculated %: C 31.68; H 3.96; N 9.24; Cl 23.43.

2-Chloromethyl thiazole (VI). A solution of 3.2 g (0.027 mole) of thionyl chloride in 10 ml of chloroform was added slowly with stirring to a suspension of 1.4 g (0.0092 mole) of 2-hydroxymethyl thiazole (m.p. 122-124°) in 14 ml of dry chloroform. The crystalline salt gradually disappeared and an oily liquid separated out. After the reaction mixture had been kept at room temperature for 30 minutes it was heated on a water bath for 1.5 hours, until there was no further liberation of gas bubbles. By the end of the heating period the substance had almost completely dissolved. After the solvent and excess thionyl chloride had been distilled under vacuum the residue was dissolved in a small amount of water, the solution was saturated with solid potash and the oil which separated out was extracted with ether. The extract was dried with anhydrous sodium sulfate, the ether was distilled and the residue was fractionated under vacuum. We obtained 0.95 g (77%) of 2-chloromethylthiazole with a b.p. of 62° (5 mm).

Found %: C 35.61; H 3.00. C_4H_4NSCl. Calculated %: C 35.95; H 2.99.

The picrate was obtained in an alcoholic solution as lustrous yellow plates with an m.p. of 126.5-127.5° (from anhydrous alcohol).

Found %: C 33.35; H 1.97; N 15.57; Cl 9.95. $C_{10}H_7O_7N_4SCl$. Calculated %: C 33.10; H 1.93; N 15.44; Cl 9.78.

5-Hydroxymethyl thiazole hydrochloride (XII). A quantity of 4.05 g of unpurified 5-hydroxymethyl thiazole was treated with 30 ml of dilute (1 : 1) hydrochloric acid. The yellow solution obtained was evaporated under vacuum. The oily residue crystallized out when triturated with a small amount of anhydrous alcohol. We obtained 2.4 g of the hydrochloride (m.p. 73-76.5°). Colorless needles with an m.p. of 83-84° were obtained after recrystallizing from anhydrous alcohol.

Found %: C 31.35; H 3.96; Cl 23.79. C_4H_6ONSCl. Calculated %: C 31.68; H 3.96; Cl 23.43.

5-Chloromethyl thiazole (XIII). A solution of 2.98 g (0.025 mole) of thionyl chloride in 7 ml of chloroform was added with stirring to a suspension of 1.2 g (0.008 mole) of 5-hydroxymethyl thiazole in 10 ml of dry chloroform; during this process the crystalline salt disappeared and a brown oil separated out. The reaction mixture was heated for 1 hour on a water bath, and the solvent and excess thionyl chloride were then distilled under vacuum. A boiling alcoholic solution of 1.65 g (0.007 mole) of picric acid was added to the residue, dissolved in a small amount of boiling anhydrous alcohol. The picrate was precipitated as dark-yellow needles with an m.p. of 103-104° (from anhydrous alcohol); 2.25 g (78.6%) was obtained.

Found %: C 33.70; H 2.02; Cl 9.44. $C_{10}H_{17}O_7N_4SCl$. Calculated %: C 33.10; H 1.93; Cl 9.78.

The picrate was treated with concentrated hydrochloric acid. The picric acid precipitated was filtered and the filtrate was evaporated under vacuum. The residue was dissolved in a small amount of water, the solution was neutralized and saturated with solid potash. The base was extracted with ether. After the extract had been dried with sodium sulfate the ether was driven off. We did not succeed in distilling the base under vacuum, because it decomposed at 60-70°.

General method for obtaining phthalimidomethyl thiazoles. A mixture of equimolecular amounts of potassium phthalimide and the corresponding chloromethyl derivative was heated with an air condenser on an oil bath at 150-180° for 2 hours. After the mixture had been heated for 40-50 minutes it was stirred and heating was continued. The cooled reaction mass was treated with water, the undissolved residue was filtered and washed with water until the wash water showed no trace of chlorides. The product was purified by recrystallizing from 96% alcohol (with charcoal). After the further recrystallization from benzene and then from alcohol, the phthalimidomethyl thiazole derivatives were obtained in an analytically pure form (see Table 1).

SUMMARY

1. By condensation of 2-chloromethyl-, 4-chloromethyl- and 2-methyl-4-chloromethyl thiazole with potassium phthalimide, good yields of 2-phthalimidomethyl-, 4-phthalimidomethyl- and 2-methyl-4-phthalimidomethyl thiazole were obtained, respectively.

2. The (2-thiazolylmethyl)-amide, (4-thiazolylmethyl)-amide, (2-methyl-4-thiazolylmethyl)-amide and (thiazolyl-5)-amide of N-acetyl sarcolysin were synthesized.

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REACTIONS OF SULFENAMIDES WITH COMPOUNDS
OF TRIVALENT PHOSPHORUS

K. A. Petrov, N. K. Bliznyuk and V. A. Savostenok

It was previously shown that neutral and acid phosphites and halogen phosphites react with alkyl hypochlorites [1], sulfenyl chlorides [2] and N-chloroamines [3] with the formation of phosphates, thiophosphates and amino-phosphates. The present paper gives the results of an investigation of reactions of sulfenamides with compounds of trivalent phosphorus. In view of the similarity of the individual chemical properties of sulfenamides and sulfenyl chlorides it was assumed that this reaction would take place similarly to the above reactions. The following were reacted with sulfenamides: a) dialkyl phosphites, dialkyl thiophosphites, monoalkyl phosphonites, dialkyl phosphinoxides, alkyl chlorophosphites and the reaction products of alkyl chlorophosphines with neutral esters of alkyl phosphinous acids; b) methyl dichlorophosphine and phosphorous trichloride.

The experiments showed that sulfenamides react with acid phosphites, thiophosphites, phosphonites and di-alkyl phosphinoxides, as in the case of sulfenyl chlorides, with formation of phosphonium compounds which decompose into thiolphosphates, thiolphosphonates and amines.

$$(RO)_2POH[SH] + R'SNR_2'' \rightarrow (RO)_2P{\Large\langle}{\genfrac{}{}{0pt}{}{SR'}{O[S]}} + R_2''NH$$

$$CH_3-P{\Large\langle}{\genfrac{}{}{0pt}{}{OR}{H}}{\atop O} + R'SNR_2'' \rightarrow CH_3P{\Large\langle}{\genfrac{}{}{0pt}{}{SR'}{OR}}{\atop O} + R_2''NH$$

$$R_2P(O)H + R'SNR_2'' \rightarrow R_2PSR' + R_2''NH \atop O$$
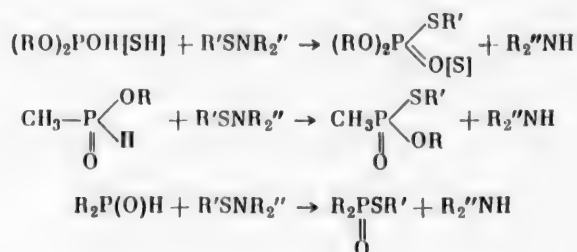
The reaction of alkyl chlorophosphites with sulfenamides also takes place with the formation of compounds of pentavalent phosphorus. However, in this case, alkyl chloride splits off from the intermediate compound formed and alkyl thiol aminophosphate is obtained with a good yield.

$$ROPCl_2 + R'SNR_2'' \rightarrow {\genfrac{}{}{0pt}{}{RO}{Cl}}{\Large\rangle}P\substack{SR' \\ | \\ -Cl \\ | \\ NR''_2} \rightarrow {\genfrac{}{}{0pt}{}{R'S}{R_2''N}}{\Large\rangle}P{\atop O}-Cl + RCl$$
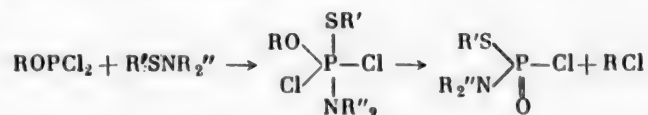
In the reaction of acyl ester chlorides of alkyl phosphinous acids with sulfenamides it was natural to expect that alkyl thiol aminophosphonates would be formed. However, the initial acyl chlorides have not been described in the literature. Attempts to obtain these substances by reacting alkyl dichlorophosphines with dialkyl phosphonites were unsuccessful. When equimolecular amounts of methyl dichlorophosphine and the dibutyl ester of methyl phosphinous acid are mixed an exothermic reaction takes place, but instead of the expected acyl ester chloride, butyl chloride is formed. This reaction may take 2 paths:

$$CH_3PCl_2 + CH_3P(OC_4H_9\text{-}n)_2 \begin{cases} \xrightarrow{(1)} 2CH_3P{\Large\langle}{\genfrac{}{}{0pt}{}{OC_4H_9\text{-}n}{Cl}} \rightarrow 2n\text{-}C_4H_9Cl + 2CH_3PO \\ \xrightarrow{(2)} {\genfrac{}{}{0pt}{}{Cl}{CH_3}}{\Large\rangle}P-O-P{\Large\langle}{\genfrac{}{}{0pt}{}{OC_4H_9\text{-}n}{CH_3}} + n\text{-}C_4H_9Cl \end{cases}$$
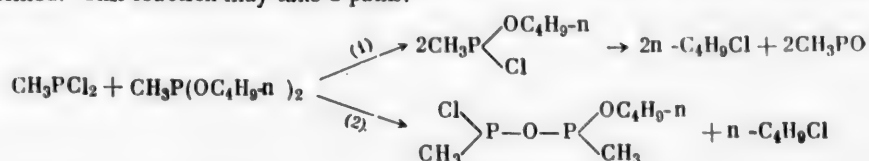
When the reaction takes place in direction (2), polyphosphonites may also be formed, as a result of further conversions. It was assumed that, irrespective of the direction of the reaction, the products of the latter would react with sulfenamides with the formation of alkyl thiol aminophosphates.

$$CH_3PO \xrightarrow{+R'SNR_2''} CH_3P\underset{O}{\overset{SR'}{\diagdown}}NR_2''$$

$$\underset{CH_3}{\overset{Cl}{\diagdown}}P-O-P\underset{CH_3}{\overset{OC_4H_9\text{-}n}{\diagup}} \xrightarrow[-n\text{-}C_4H_9Cl]{+2R'SNR_2''} 2CH_3-P=O \begin{array}{c} SR' \\ | \\ NR_2'' \end{array}$$
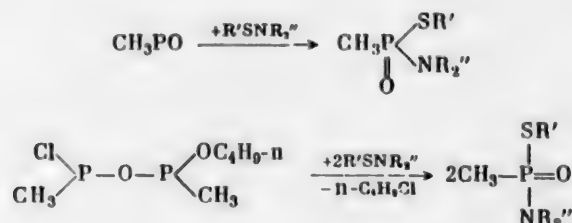
Aminothiophosphonates must be formed if the sulfenamide is attached to the other phosphorus atom of pyrophosphonite or reacts with polyphosphonites. Our experiments confirmed this assumption. When sulfenamides react with an equimolecular mixture of methyl chlorophosphine and the dibutyl ester of methyl phosphinous acid, alkyl thiol aminophosphonates are obtained with a good yield.

$$CH_3PCl_2 + CH_3P(OC_4H_9\text{-}n)_2 + 2R'SNR_2'' \rightarrow 2CH_3\overset{O}{\underset{}{P}}\diagup\overset{SR'}{\underset{NR_2''}{}} + 2n\text{-}C_4H_9Cl$$
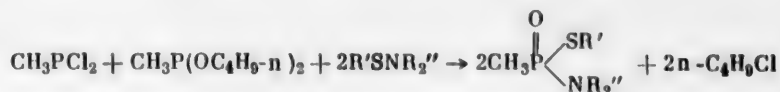
Methyl dichlorophosphine and phosphorus trichloride react vigorously with sulfenamides, even at low temperatures. During this process, methyl dialkylaminoalkylthiol phosphorus dichloride (A) and dialkyl aminoalkyl-thiol phosphorus trichloride (B) are formed respectively. In contrast to the above-considered addition products, these substances do not have mobile hydrogen atoms or ester groups in the molecules; they are therefore considerably stable and do not decompose in the ordinary way. For example, the addition product of S-ethyl-N-diethylamine and methyl dichlorophosphine is a crystalline substance which remains unchanged for a considerable period. Like alkyl phosphorus tetrachlorides, they are decomposed by sulfur dioxide with the formation of derivatives of phosphinic or phosphoric acids. Thus, when methyl dichlorophosphine reacted with sulfenamides, alkyldialkylamino-thiol phosphonates contaminated by chlorine-containing impurities were formed.

$$CH_3PCl_2 \xrightarrow{RSNR_2'} CH_3-\underset{\underset{NR_2'}{|}}{\overset{\overset{SR}{|}}{P}}\diagdown\overset{Cl}{\underset{Cl}{}} \xrightarrow[-SOCl_2]{+SO_2} CH_3-\underset{\underset{NR_2'}{|}}{\overset{\overset{SR}{|}}{P}}{=}O$$
$$(A)$$
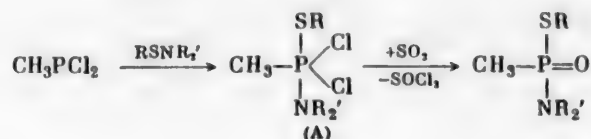
When phosphorus trichloride reacted with sulfenamides in sulfurous acid, the alkyl thiodichlorophosphate obtained also had an admixture of other products which were difficult to separate. [*]

$$PCl_3 \xrightarrow{RSNR_2'} \underset{\underset{NR_2'}{|}}{RS-PCl_3} \xrightarrow[-R_2'NSOCl]{+SO_2} \underset{\underset{O}{\|}}{RS-PCl_2}$$
$$(B)$$
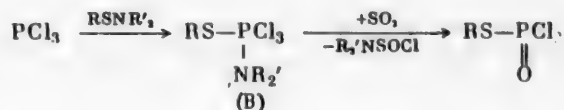
Together with the derivatives of phosphinic and phosphoric acids, obtained in low yields, a large amount of tarry substances is formed; this indicates that the course of the reaction of methyl dichlorophosphine and phosphorus trichloride with sulfenamides is not simple.

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[*] Phosphorus halides can dissociate into the initial components. Thus, when the addition product of methyl dichlorophosphine and ethyl sulfenyldiethylamine is heated to 70°, methyl dichlorophosphine is obtained; we did not succeed in separating the second component.

In addition to these reaction directions, which must be assumed to occur in both the first and second case, we may assume that there is a decomposition reaction of the addition products of sulfenamides and methyl dichlorophosphine and phosphorus trichloride, which takes place with detachment of alkyl halide and formation of derivatives of thiophosphinic and thionphosphoric acids.

$$\underset{\underset{SR}{\overset{\overset{NR_2'}{|}}{|}}}{CH_3-PCl_2} \xrightarrow{-RCl} \underset{\underset{S}{\overset{\overset{NR_2'}{|}}{|}}}{CH_3-PCl}$$

$$\underset{\underset{SR'}{|}}{R_2N-PCl_3} \xrightarrow{-R'Cl} \underset{\underset{S}{\|}}{R_2NPCl_2}$$
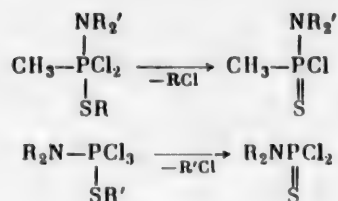
Similar decomposition was observed previously during the reaction of sulfenyl chlorides with triphenyl phosphite [2].

Sulfenamides were obtained by the reaction of sulfenyl chlorides with amines. Attempts to obtain butyl sulfenyldiethylamine by analogy with N,N'-diisopropyl-2-benzothiazole sulfenamide [4] by the reaction of diethyl-chloramine on a mixture of dibutyl disulfide and diethylamine were unsuccessful.

Dialkyl phosphinoxides were obtained by the reaction of sodium ethyl phosphite with alkyl magnesium bromides.*

$$(C_2H_5O)_2PONa + 2RMgX \rightarrow R_2PONa \xrightarrow{H_2SO_4} R_2P(O)H$$

Methyl chlorophosphine was obtained by the method described in the literature [6], the only difference being that it was distilled over magnesium to purify it from admixtures.

EXPERIMENTAL

Alkyl thiolphosphates and phosphonates (description of standard experiment). An equimolecular mixture of sulfenamide and dialkyl phosphite (dialkyl thiophosphite, monoalkyl phosphonite or dialkyl phosphinoxide) was kept in a flask (prepared for vacuum distillation) at 100-120° for 1-2 hours. After a nearly theoretical amount of amine had been distilled, the residue was distilled under vacuum. The yield was 75-95%. The properties of the compounds obtained and the analytical data are given in the table (compounds No. 1-10).

Alkyl thiolaminophosphosphates (standard experiment). An equimolecular amount of sulfenamide was added to alkyl dichlorophosphite (or dialkyl chlorophosphite) in a vacuum distillation flask. When a nearly theoretical amount of alkyl chloride had been collected in the cold trap (or receiver), the residue was distilled. The yield was 85-90%. The properties of the compounds obtained and the analytical data are given in the table (compounds No. 11-13).

Alkyl thiolaminophosphonates (standard experiment). An equimolecular amount of the neutral ester of alkyl phosphinous acid was added with shaking to alkyl dichlorophosphine in a vacuum distillation flask, a current of dry carbon dioxide or nitrogen being passed. The reaction mass was kept for 30-60 min and the theoretical amount of sulfenamide was then added. After the alkyl chloride had been distilled the residue was distilled under vacuum. The yield was 80-85%. The properties of the compounds obtained and the analytical data are given in the table (compounds No. 14-15).

Reaction of methyl dichlorophosphine with the dibutyl ester of methyl phosphinous acid. A quantity of 3 g (0.0156 g mole) of the dibutyl ester of methyl phosphinous acid was added to 1.83 g (0.0156 g - mole) of methyl di-chlorophosphine in a vacuum distillation flask; during this process the temperature rose to 60°. The reaction mixture was left overnight; when it was kept under vacuum, 2.7 g of butyl chloride (b.p. 75-77°, n_D^{20} 1.4102) condensed in the cold trap.

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* Dialkyl phosphinoxides were obtained previously [5] by the reaction of alkyl magnesium halides with dialkyl phosphites in 3 : 1 molar ratios, 1 mole of alkyl magnesium halide being decomposed to hydrocarbon during this process.

Serial No.	Formula	Boiling point (pressure in mm)	d_4^{20}	n_D^{20}	MR_D found	MR_D calculated	Found (%) P	Found (%) S	Found (%) N	Calculated (%) P	Calculated (%) S	Calculated (%) N	Initial products
1	$(C_2H_5O)_2P(O)(SC_4H_9\text{-}n)$	136° (10)	1.0541	1.4591	58.71	58.18	13.82	14.26	—	13.69	14.17	—	(I, R = C$_2$H$_5$), (II)
2	$(n\text{-}C_3H_7O)_2P(O)(SC_4H_9\text{-}n)$	151—153 (8)	1.0091	1.4567	68.60	68.00	12.30	12.70	—	12.18	12.61	—	(I, R = C$_3$H$_7$-n), (II)
3	$(\text{iso-}C_3H_7O)_2P(O)(SC_4H_9\text{-}n)$	143—145 (15)	1.0096	1.4533	68.12	68.05	12.28	12.84	—	12.18	12.61	—	(I, R = C$_3$H$_7$-iso), (II)
4	$(n\text{-}C_4H_9O)_2P(O)(SC_4H_9\text{-}n)$	160 (8)	1.0013	1.4582	77.01	77.35	11.02	11.46	—	10.97	11.35	—	(I, R = C$_4$H$_9$-n), (II)
5	$(n\text{-}C_4H_9O)_2P(S)(SC_4H_9\text{-}n)$	160—163 (5)	1.0124	1.4831	84.19	84.38	10.4	10.81	—	10.38	10.74	—	(III, R = C$_4$H$_9$-n), (II)
6	$CH_3P(O)(OC_2H_5)(SC_2H_5)$	92—94 (8)	1.0697	1.4711	43.96	43.15	18.63	19.10	—	18.42	19.07	—	(IV, R = C$_2$H$_5$), (V)
7	$CH_3P(O)(CC_4H_9\text{-iso})(SC_4H_9\text{-iso})$	137—141 (12)	1.0000	1.4659	62.10	62.064	13.86	14.42	—	13.81	14.30	—	(IV, R = C$_4$H$_9$- iso), (II)
8	$CH_3P(O)(OC_4H_9\text{-}n)(SC_4H_9\text{-}n)$	143—146 (13)	1.0065	1.4681	61.96	62.03	13.87	14.48	—	13.81	14.30	—	(IV, R = C$_4$H$_9$-n), (II)
9	$CH_3P(O)(OC_6H_{13}\text{-}n)(SC_4H_9\text{-}n)$	163—165 (9)	0.9818	1.4672	71.33	71.38	12.37	12.84	—	12.28	12.71	—	(IV, R = C$_6$H$_{13}$-n), (II)
10	$(n\text{-}C_8H_{17})_2P(O)(SC_4H_9\text{-}n)$	220—224 (4)	0.9199	1.4810	112.18	112.33	8.76	8.96	—	8.54	8.84	—	(VI, R = C$_8$H$_{17}$-n), (II)
11	$(CH_3)_2NP(O)(SC_4H_9\text{-iso})Cl$	123—124 (6)	1.1536	1.4970	54.71	54.44	13.86	15.61	6.57	14.36	14.87	6.49	(VII, R = C$_2$H$_5$), (VIII)
12	$(C_2H_5)_2NP(O)(SC_4H_9\text{-}n)Cl$ **	128—129 (4)	1.1059	1.4962	64.40	63.89	14.05	13.88	4.93	12.71	13.15	5.74	(VII, R = C$_2$H$_5$), (II)
13	$(C_2H_5)_2NP(O)(OC_2H_5)(SC_4H_9\text{-}n)$	125—126 (4)	1.0210	1.4698	69.20	69.73	11.82	13.12	5.32	12.22	12.66	5.53	(IX, R = C$_2$H$_5$), (II)
14	$CH_3P(O)(SC_4H_9\text{-}n)N(C_2H_5)_2$	126—127 (7)	1.0055	1.4870	63.88	63.80	13.95	14.55	6.30	13.87	14.36	6.27	(X), (XI), (II)
15	$CH_3P(O)(SC_4H_9\text{-iso})N(CH_3)_2$	134—135 (7)	1.0299	1.4872	54.55	54.49	13.50	16.47	7.42	15.86	16.42	7.17	(X), (XI), (V)

* The following symbols are used in the "Initial products" column: $(RO)_2POH$ (I), $n\text{-}C_4H_9SN(C_2H_5)_2$ (II), $(RO)_2P(S)H$ (III), $CH_3P(O)H(OR)$ (IV), $C_2H_5SN(C_2H_5)_2$ (V), $R_2P(O)H$ (VI), $(RO)PCl_2$ (VII), $\text{iso-}C_4H_9SN(CH_3)_2$ (VIII), $(RO)_2PCl$ (IX), CH_3PCl_2 (X) and $CH_3P(OC_4H_9\text{-}n)_2$ (XI).

** Found %: Cl 13.8. Calculated %: Cl 14.54.

Reaction of methyl dichlorophosphine with alkyl sulfenamides. A quantity of 11.7 g of n-butyl sulfenyl-diethylamine was added with stirring to a solution of 8.5 g of methyl dichlorophosphine with 25 ml of sulfur dioxide, cooled to -50°. After the sulfur dioxide had been evaporated the residue was distilled under vacuum. After two distillations, we obtained 1.6 g (10%) of the S-butyl ester of diethyl amino methyl phosphinic acid, contaminated by chlorine-containing products:

B.p. 105-108° (6 mm), d_4^{20} 1.1195, n_D^{20} 1.5023.

Found %: P 14.65; S 16.09; N 6.24; Cl 1.69. $C_9H_{22}ONPS$. Calculated %: P 13.87; S 14.36; N 6.27.

Under similar conditions we obtained 1.8 g (31%) of the S-ethyl ester of diethyl amino methyl phosphinic acid (also with chlorine-containing impurities) from 4 g (0.03 g-mole) of ethyl sulfenyldiethylamine and 3.5 g (0.03 g mole) of methyl dichlorophosphine:

B.p. 90-91° (4 mm), d_4^{20} 1.1996, n_D^{20} 1.5032.

Found %: P 14.92; S 16.30; N 6.18; Cl 2.5. $C_7H_{18}ONPS$. Calculated %: P 15.86; S 16.42; N 7.17.

Reaction of phosphorus trichloride with n-butyl sulfenyldiethylamine in sulphurous acid. We obtained 3.5 g (42%) of S-butyl dichlorophosphate from 5.5 g (0.04 g-mole) of phosphorus trichloride and 6.44 g (0.04 g-mole) of n-butyl sulfenyldiethylamine:

B.p. 107-110° (15 mm), d_4^{20} 1.2900, n_D^{20} 1.5110.

Found %: P 13.70; S 16.52; Cl 16.96. $C_4H_9OPSCl_2$. Calculated %: P 14.96; S 15.49; Cl 17.12.

SUMMARY

It is shown that sulfenamides react with dialkyl phosphites, dialkyl thiophosphites, monoalkyl phosphonites, dialkyl phosphinoxides, alkyl dichloro- and dialkyl chlorophosphites and the reaction products of alkyl dichlorophosphines with dialkyl phosphonites, with the formation of thiol phosphates, phosphonates, aminoalkyl thiolphosphates and aminoalkyl thiolphosphonates,respectively.

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REACTIONS OF SULFENYL CHLORIDES AND N-CHLORAMINES
WITH PHOSPHORUS TRICHLORIDE, DICHLOROPHOSPHINES
AND RED PHOSPHORUS

K. A. Petrov, A. A. Neimysheva, G. V. Dotsev,
and A. G. Barich

To obtain compounds with a pentavalent phosphorus atom, neutral and acid phosphites and chlorophosphites are often used, being reacted with alkyl halides, halogen hydracids, halides, cyanogen halides, alkyl hypochlorites, sulfenyl chlorides, N-chloramines [1], etc. These reactions are due to the tendency of compounds of trivalent phosphorus to attach themselves to various substances, with the formation of unstable products which can undergo further conversions. In the present work the reaction of sulfenyl chlorides and N-chloramines with phosphorus tri-chloride, chlorophosphines and elementary phosphorus was investigated with the aim of obtaining derivatives of phosphoric and phosphinic acids.

Our experiments showed that sulfenyl chloride reacts vigorously with phosphorus trichloride with the formation of alkyl thiophosphorus tetrachlorides, which by the action of sulfur dioxide are converted to alkyl thiodichloro-phosphates.

$$PCl_3 + RSCl \rightarrow RSPCl_4 \xrightarrow[-SOCl_2]{+SO_2} RSPOCl_2$$

Alkyl thiophosphorus tetrachlorides were not separated in individual form. A better yield of alkyl thio-dichlorophosphates is obtained if the reaction is carried out in a medium of sulfur dioxide at low temperature and the sulfenyl chlorides are added to phosphorus trichloride. The thiochlorophosphates obtained in this way always contained dialkyl disulfides as impurities which could not be separated because of the proximity of their melting points. The formation of disulfide may be explained by a secondary reaction of alkyl thiophosphorus tetrachloride or alkyl thiodichlorophosphate with sulfenyl chloride, taking place via sulfonium halide.

$$RSPCl_4 + RSCl \rightarrow \left[\begin{matrix} R \\ RS \end{matrix} \!\! \stackrel{+}{S}-PCl_4 \right] \bar{Cl} \rightarrow R-S-S-R + PCl_5$$

$$RSPOCl_2 + RSCl \rightarrow \left[\begin{matrix} R \\ RS \end{matrix} \!\! \stackrel{+}{S}-POCl_2 \right] \bar{Cl} \rightarrow R-S-S-R + POCl_3$$
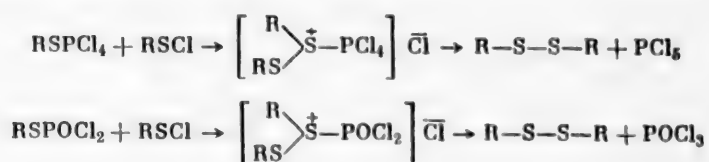
When the reaction is carried out in excess sulfenyl chloride, i.e., when phosphorus trichloride is added to sulfenyl chloride, and at elevated temperature, the yield of disulfide is increased. The possibility of the formation of disulfide by the reaction of thiodichlorophosphate with sulfenyl chlorides is confirmed by the fact that when ethyl sulfenyl chloride reacted with triethyl thiophosphate a 67% yield of diethyl disulfide was obtained, together with a small amount of diethyl chlorophosphate and a high-boiling substance which was evidently tetraethyl thio-pyrophosphate.*

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* It was previously shown that the reaction of thiophosphates with chlorine and sulfuryl chloride takes place at low temperatures with the formation of dialkyl chlorophosphates and sulfenyl chlorides [2].

Compound	Yield (%)	Boiling point (pressure in mm)	d_4^{20}	n_D^{20}	Calculated (%)		Found (%)	
					P	S	P	S
$C_9H_5SPOCl_2$ *	50.0	87—88° (15)	1.4040	1.5279	17.32	17.88	15.85	16.78
$(n-C_4H_9SPOCl_2$	75.0	113—114 (15)	1.2395	1.5037	14.98	15.46	14.70	16.12
iso -$C_4H_9SPOCl_2$	75.0	96—97.5 (6)	1.2192	1.5002	14.98	15.46	12.29	19.21
iso -$C_5H_{11}SPOCl_2$	79.0	114—115 (8)	1.2020	1.5044	14.01	14.50	13.74	14.80
$(C_2H_5S)(C_6H_5O)POCl$ **	52.0	144—145 (5)	1.2920	1.5508	13.11	13.53	13.16	14.20
$(C_6H_5O)_2P(O)SC_2H_5$	78.0	222—224 (9)	1.2290	1.573	10.54	10.88	10.10	11.36
$(C_2H_5S)(C_2H_5O)POCl$ ***	91.0	95—96 (5)	1.2234	1.4844	16.44	16.98	16.05	16.56
$(CH_3)(C_2H_5S)POCl$ ****	78.6	75—76 (3)	1.2578 (17°)	1.5132 (18°)	19 96	20.46	20.19	19.82
$(CH_3)(n-C_4H_9S)POCl$	79.0	117—118 (8)	1.1551	1.5098	16.62	17.16	16.35	17.28
$(CH_3)(iso -C_4H_9S)POCl$	98.0	116—118 (12)	1.1710	1.5107	16.62	17.16	15.13	18.73
$(CH_3)(iso -C_5H_{11}S)POCl$	82.0	133—134 (15)	1.1310	1.5018	15.46	15.96	15.61	16.21
$(C_6H_5)(iso -C_4H_9S)POCl$	95.0	169.5—171.5 (3)	1.1930	1.5746	12.47	12.85	12.88	13.25
$(C_6H_5)(n-C_4H_9S)POCl$	89.0	175.5—177 (3)	1.2172	1.5748	12.47	12.85	12.88	12.91

* In the literature the b.p. is given as 94-95° (17-18 mm), d_4^{20} 1.4055, n_D^{20} 1.5153 [1].
** Found %: Cl 15.02. $C_8H_{10}O_2SPCl$. Calculated %: Cl 15.01.
*** In the literature the b.p. is given as 98-99° (7-8 mm) [1].
**** In the literature the b.p. is given as 50° (0.3 mm) [5].

The reaction of sulfenyl chlorides with methyl and phenyl dichlorophosphines takes place similarly to the reaction with phosphorus trichloride, acyl chlorides of thioethers of alkyl phosphinic acids being obtained in almost qualitative yield.

$$RPCl_2 + R'SCl + SO_2 \rightarrow \begin{matrix} R \\ P'S \end{matrix}\!\!\!>\!\!POCl + SOCl_2$$
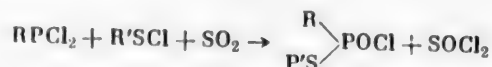
The method of preparation which we developed is simple and makes it possible to obtain various acyl chlorides of thioethers of alkyl phosphinic acids. The reaction was investigated by way of examples of the reaction of methyl and phenyl dichlorophosphine with n-butyl, isobutyl and isoamylsulfenyl chlorides.

On the basis of the investigation of the reaction of sulfenyl chlorides with phosphorus trichloride and dichlorophosphines it might be expected that the corresponding thiophosphates would also be obtained when sulfenyl chlorides react with chlorophosphites in sulfurous acid. This assumption was only correct for the reaction of sulfenyl chlorides with phenyl dichlorophosphite and diphenyl chlorophosphite, when O-phenyl-S-alkyl chlorophosphate and O,O-diphenyl-S-alkyl phosphate are obtained in good yield. The reaction of sulfenyl chlorides with alkyl chlorophosphites in sulfurous acid did not give the expected results; it took place in the usual way with liberation of alkyl halide and formation of thiochlorophosphates. The data obtained agree with the greater strength of the Ar−O bond and stability of aryl phosphorus halides compared with the strength of the Alk−O bond and the properties of alkoxy phosphorus halides, which cannot be isolated in the free form.

Like sulfenyl chlorides dialkyl chloroamines also react vigorously with phosphorus trichloride and alkyl dichlorophosphines, with the formation of dialkyl aminophosphorus tetrachlorides and dialkyl aminoalkyl phosphorus trichlorides respectively, which are decomposed by the action of sulfur dioxide: the first being converted to aminochlorophosphate and phosphorus oxychloride, the second to aminochlorophosphonate and the diacyl chloride of alkyl phosphinic acid.

$$PCl_3 + R_2NCl \rightarrow R_2NPCl_4 \begin{cases} \xrightarrow[-SOCl_2]{+SO_2} R_2NPOCl_2 \\ \xrightarrow[-R_2NSOCl_2]{+SO_2} POCl_3 \end{cases}$$

$$R'PCl_2 + R_2NCl \rightarrow (R')(R_2N)PCl_3 \left[\begin{array}{l} \xrightarrow[-SOCl_2]{+SO_2} \quad \begin{array}{c} R' \\ R_2N \end{array}\!\!>\!POCl \\[2mm] \xrightarrow[-R_2NSOCl_2]{+SO_2} \quad R'POCl_2 \end{array} \right.$$
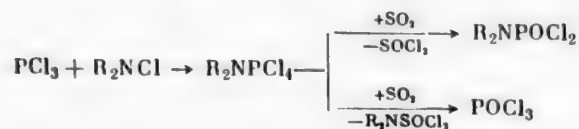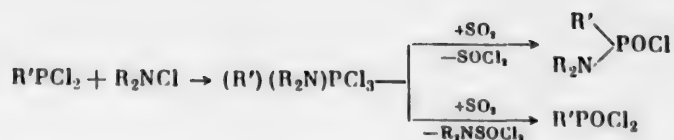
In contrast to dialkyl chloramines, ethyl dichloramine reacts less vigorously with phosphorus trichloride. The reaction was carried out at different ratios of the reagents, different orders of mixing and various temperatures. In all cases, a substance was precipitated after treatment of the reaction mass with sulfur dioxide, which from its chlorine, nitrogen and phosphorus content was the diacyl chloride of the ethylidenamide of phosphoric acid. It must be assumed that with a molecule of phosphorus trichloride, ethyl dichloramine forms N-chloroethylamino-phosphorus tetrachloride, which, when acted on by sulfur dioxide, exchanges two chlorine atoms for oxygen and splits off hydrogen chloride.

$$C_2H_5NCl_2 + PCl_3 \rightarrow C_2H_5 - \underset{\underset{Cl}{|}}{N} - PCl_4 \xrightarrow{+SO_2} CH_3 - CH = N - POCl_2 + HCl$$
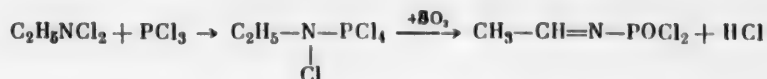
It is quite possible that the detachment of hydrogen chloride takes place as a result of heating during the process of distillation of the substance. The low yield of the endproduct is partly explained by the effect of splitting off hydrogen chloride, particularly during heating.

We used chloroform or carbon tetrachloride as the solvent in these reactions. Sulfurous acid was unsuitable as a solvent because, as we have shown, dialkyl chloramines react with sulfur dioxide in the cold, forming dialkyl-amides of chlorosulfonic acid.

$$(C_2H_5)_2NCl + SO_2 \rightarrow (C_2H_5)_2NSO_2Cl$$

The reaction of sulfenyl chlorides with red phosphorus is not simple. Thus, for any order of mixing of these reagents in sulfurous acid at -20-30°, disulfide, alkyl thiodichlorophosphate and S,S,-dialkyl chlorophosphate precipitated out from the reaction mass.

Ethyl and n-butyl sulfenyl chloride were introduced into the reaction with red phosphorus. In the latter case we did not succeed in separating the disulfide and n-butyl thiodichlorophosphate by fractionation under vacuum. Dichlorothiophosphate was converted to tributyl thiophosphate, which was isolated in individual form.

The physical properties of the substances obtained are given in the table.

EXPERIMENTAL

Standard description of the reaction of phosphorus trichloride, methyl and phenyl dichlorophosphines, alkyl and aryl chlorophosphites with sulfenyl chlorides in sulfurous acid (by way of example of the reaction of PCl_3 with sulfenyl chloride). Sulfenyl chloride (0.1 mole) was added with stirring to a cooled (-50°) solution of phosphorus trichloride (0.11 mole) in a 3-5 fold amount of SO_2 (as sulfurous acid) at such a rate that the temperature of the reaction mixture did not exceed -15°, after which it was slowly raised to room temperature. The thionyl chloride was distilled under a low vacuum and the residue was then fractionated under vacuum. The yields, properties and analytical data of the compounds obtained are given in the table.

Alkyl dichlorothiophosphates are usually obtained with an admixture of dialkyl disulfides, the amount of which increases when the procedure of mixing the components is reversed and with an increase in the reaction temperature. The admixture of disulfides is removed by treating the product with sulfuryl chloride at room temperature.

The reaction of triethyl thiophosphate with ethyl sulfenyl chloride. A quantity of 5 g of ethyl sulfenyl chloride was added dropwise to 10.3 g of triethyl thiophosphate, a slight rise in temperature being observed. The mixture was kept at room temperature for 0.5 hours, it was then heated on a water bath for 0.5 hours and fractionated. 4.25 g (67.3%) of diethyl disulfide was obtained; the b.p. was 60-65° (30 mm), 148-150° (748 mm), d_4^{20} 0.9980.

Reaction of red phosphorus with ethyl sulfenyl chloride. A quantity of 20.1 g of ethyl sulfenyl chloride was added dropwise with stirring and cooling (to -50-60°) over a period of 15-20 minutes to a suspension of 2.15 g of red phosphorus in 30 ml of sulfurous acid. The reaction mixture was then kept at -20 to -30° for 1 hr, during which time the color of the solution changed from red to dirty-green. After evaporation of the sulfur dioxide and distillation of the thionyl chloride the residue was fractionated under vacuum. Three fractions were isolated: 1st fraction, b.p. 40-43° (8 mm), 4.4 g; 2nd, b.p. 80-82.5° (9 mm), 4.0g;3rd, b.p. 120-130° (9 mm), 4.7 g.

The 1st fraction was practically pure diethyl disulfide, b.p. 48-49° (18 mm), d_4^{20} 1.0420, n_D^{20} 1.5103. After redistillation of the 2nd fraction a substance with b.p. 70-72° (6 mm), d_4^{20} 1.4030 and n_D^{20} 1.5193 was obtained its constants corresponding to those of ethyl thiodichlorophosphate [b.p. 94-95° (17-18 mm), d_4^{20} 1.4055 and n_D^{20} 1.5153]. Redistillation of the 3rd fraction gave a substance with a b.p. of 129-131.5° (6 mm), d_4^{20} 1.2705 and n_D^{20} 1.5808, corresponding in sulfur and phosphorus contents to S,S-diethyl chlorophosphate.

Found %: P 15.37, 15.17; S 30.22, 30.48. $C_4H_{10}OS_2PCl$. Calculated %: P 15.16; S 31.30.

Reaction of red phosphorus with n-butyl sulfenyl chloride. Two fractions were obtained by distillation of the reaction mixture obtained by reacting 35.7 g of n-butyl sulfenyl chloride and 2.96 g of red phosphorus under the above-described conditions; the 1st fraction had a b.p. of 93-105° (7 mm), the weight was 22.4 g; the b.p. of the 2nd fraction was 150-180° (7 mm), the weight was 9.1 g. After repeated distillation of the 2nd fraction a substance was isolated with b.p. 160-161° (3 mm), d_4^{20} 1.1424 and n_D^{20} 1.5790, corresponding in phosphorus content to S,S-dibutyl chlorophosphate.

Found %: P 12.09, 12.15. $C_8H_{18}OS_2PCl$. Calculated %: P 11.90.

From the analytical data (found %: P 7.28; S 27.65; Cl 15.57) the 1st fraction was a mixture of dibutyl disulfide and n-butyl thiodichlorophosphate, which we did not succeed in isolating by repeated fractionation under vacuum. To separate the substances, the mixture was treated with n-butyl alcohol in the presence of triethylamine. A quantity of 10 g of n-butyl alcohol was added dropwise with stirring to a solution of 28.9 g of a mixture of disulfide and chlorophosphate and 12.8 g of triethylamine in 50 ml of dry benzene. The reaction mixture was heated with stirring for 2 hours, the triethylamine hydrochloride was filtered and the benzene solution was washed three times with small amounts of water. After the solution had been dried over $MgSO_4$ the benzene was distilled under a low vacuum and the residue was fractionated; we obtained 14.9 g of dibutyl disulfide with a b.p. of 100-102° (7 mm), d_4^{20} 0.9371 and n_D^{20} 1.4922 and 9.1 g of O,O-dibutyl-S-butyl phosphate with a b.p. of 162-163° (8 mm), d_4^{20} 1.0010 and n_D^{20} 1.4590. The following values are given for this substance in the literature: b.p. 160° (8 mm), d_4^{20} 1.0013 and n_D^{20} 1.4582 [3].

Diacyl chloride of diethylamide of phosphoric acid. A quantity of 4.7 g of phosphorus trichloride was added with stirring and cooling (to -15 to -20°) over a period of 30 minutes to a solution of 3.7 g of diethylchloramine in 15 ml of dry carbon tetrachloride. The reaction was strongly exothermic, a copious white precipitate of a phosphonium compound coming out during this process. When all the reagents had been added the mixture was stirred until heat was no longer liberated; sulfur dioxide was then passed until all the precipitate had dissolved, the rate of feed being such that the temperature of the mixture did not exceed -15°. After the solvent and highly volatile substances had been distilled, the residue was fractionated under vacuum. We obtained 2 g (30.8%) of the diacyl chloride of the diethylamide of phosphoric acid. The b.p. was 79-81° (11 mm), d_4^{20} 1.2492 and n_D^{20} 1.4640. The following values for this substance are given in the literature: b.p. 80-81° (11 mm), d_4^{20} 1.2527 [4].

Diacyl chloride of the dimethylamide of phosphoric acid. We obtained 6.2 g (49.2%) of the diacyl chloride of the dimethylamide of phosphoric acid [b.p. 83-84° (16 mm), d_{20}^{20} 1.3772 and n_D^{20} 1.4650] from 6 g of dimethylchloramine and 10.7 g of phosphorus trichloride under the above-given conditions and after redistillation.

Reaction of ethyldichloramine with phosphorus trichloride. A quantity of 16.4 g of phosphorus trichloride was added slowly with stirring and cooling to 0-5° to a solution of 13.6 g of ethyldichloramine in 20 ml of dry carbon tetrachloride. The reaction mixture was stirred until liberation of heat had ceased, and sulfur dioxide was then passed at -15 to -20°. After redistillation under vacuum, we obtained 5.5 g of a substance, which from its chlorine, phosphorus and nitrogen contents corresponded to the diacyl chloride of the ethylidenamide of phosphoric acid.

B.p. 108-110° (3.2 mm), d_{20}^{20} 1.3858, n_D^{20} 1.4739, MR_D 32.33; calc. 31.84.

Found %: Cl 43.21; P 17.96; N 8.29. $C_2H_4ONPCl_2$. Calculated %: Cl 44.38; P 19.37; N 8.75.

Diethylamide of chlorosulfonic acid. Sulfur dioxide was passed into a solution of 5 g of diethylchloramine in 15 ml of dry carbon tetrachloride (with cooling by ice water) until all "active" chlorine had disappeared. After the solvent had been distilled the residue was fractionated under vacuum. A quantity of 3.5 g (43.8%) of the diethylamide of chlorosulfonic acid was obtained.

B.p. 92-93° (12 mm), d_{20}^{20} 1.2275, n_D^{20} 1.4553, MR_D 38.05; calc. 38.05.

Found %: N 8.10, 8.15; S 18.98, 19.12; Cl 21.07. $C_4H_{10}O_2NSCl$. Calculated %: N 8.16; S 18.66; Cl 20.70.

Reaction of methyl dichlorophosphine with diethylchloramine. From 4.1 g of methyl dichlorophosphine and 3.75 g of diethylchloramine we obtained, under the above-described conditions, 2.1 g of the diacyl chloride of methyl phosphinic acid with a b.p. of 51-52° (10 mm), 160-161° (760 mm), and 1.2 g of the acyl chloride of methyl-phosphinic acid diethylamide with a b.p. of 107-109° (9 mm) and n_D^{20} 1.4708.

Found %: Cl 23.1. $C_5H_{13}ONPCl$. Calculated %: Cl 20.94.

Literature data for this substance are b.p. 115-115.5° (9 mm), d_4^{20} 1.1274, n_D^{20} 1.4648 [4].

SUMMARY

1. It was established that a high yield of acyl chlorides of thioethers of phosphoric and alkyl phosphinic acids and small amounts of disulfides are obtained when phosphorus trichloride and alkyl dichlorophosphines react with sulfenyl chlorides.

2. It was shown that when red phosphorus reacts with sulfenyl chlorides in sulfurous acid, S-alkyl dichloro-phosphates, S,S-dialkyl chlorophosphates and dialkyl disulfides are formed.

3. It was established that phosphorus trichloride reacts with dialkyl chloramines with the formation of diacyl chlorides of dialkyl amides of phosphoric acid.

4. It was established that dialkyl chloramines react with sulfur dioxide with the formation of dialkyl amides of chlorosulfonic acid.

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STEROIDS

IX. THE STEREOSPECIFICITY OF THE HYDROGENATION OF STEROID

Δ^4-3-KETO UNSATURATED COMPOUNDS*

N. N. Suvorov and Z. A. Yaroslavtseva

In our synthesis of cortisone acetate from solasodine we employed hydrogenation of 11α-hydroxyprogesterone (I) in pyridine, using 10% palladium on calcium carbonate as catalyst; this method gave a 90% yield of pregnanol-11α-dione-3, 20 (II). The amount of the corresponding allo compound (III) was very small [2]:
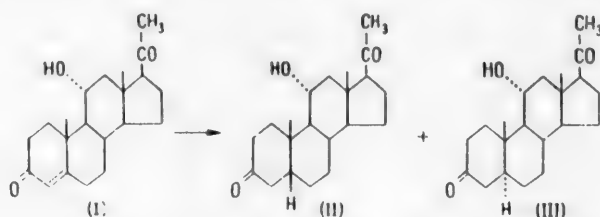
This method was successfully extended by the authors to the hydrogenation of $\Delta^{5,16}$-pregnandienol-3 β-one-20 acetate to pregnenolone acetate [3]. The present paper gives the results of the hydrogenation of 11α-hydroxy-progesterone in various solvents, and also the influence of a substituent in the 11-position on the selectivity of hydrogenation in pyridine.

The hydrogenation of 11α-hydroxyprogesterone was first investigated by Djerassi and his co-workers in their well-known work on the conversion of progesterone to cortisone [4]. These investigators showed that the hydrogenation of 11α-hydroxyprogesterone with 10% palladium on calcium carbonate in alcohol gives 33% of the allo form (III). The addition of alkali [5] made it possible to reduce the amount of the latter to 5%. It must be noted that in these experiments the allo form was separated by trituration of the hydrogenation product with ether, the normal form (II) being isolated as the acetate.

Since this method did not give sufficiently clear separation, we boiled the hydrogenation product with a 5-fold amount of carbon tetrachloride, filtered the allo compound, and the remaining pregnanol-11α-dione-3, 20 was oxidized with Kiliani's reagent without being purified. Allopregnantrione-3,11,20 may be separated from the oxidation product as a result of its low solubility in a mixture of methylene chloride and ether. Thus, we showed that with hydrogenation of 11α-hydroxyprogesterone with the above-mentioned catalyst in pyridine the amount of the allo form is 2 to 4%. It should be pointed out that in this case the mixing intensity has a marked effect on the ratio between the normal and the allo forms: with very rapid mixing the rate of hydrogenation increases, and the content of the allo form increases parallel with this (to 8-12%). Hydrogenation in alcohol gave 49.3% of the allo form. In contrast to the data of American investigators, we obtained only a slight reduction (to 43.9%) in the allo form by the addition of caustic potash. On the contrary, in dioxan in accordance with the indications of Djerassi and his co-workers, a considerable reduction in the amount of allo form obtained occurs in the presence of alkali: 45.4% without alkali and 14.6% in the presence of caustic potash.

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* For communication VIII, see the article of N. N. Suvorov et al. Microbiologic Deacylation of Corticosteroid-21 Acetates [1].

These data indicate that the maximum stereospecificity of hydrogenation of 11α-hydroxyprogesterone over palladium catalyst is observed in the presence of pyridine. It was of interest to determine whether this high selectivity was maintained during the hydrogenation of progesterone and its 11-substituents.

Pearlman [6] indicates that during hydrogenation of progesterone in anhydrous alcohol in the presence of palladium on zirconium oxide, the main product formed is allopregnandione-3,20 with a small admixture of the normal form. During hydrogenation in pyridine with 10% palladium on calcium carbonate we obtained principally pregnandione-3,20 (79.5%), but the yield of the allo product was only 11.1%.

Under our conditions, hydrogenation of 11-keto progesterone gave 75.3% of allopregnantrione-3,11,20 and 17.4% of the normal form. The preferential formation of the allo product in this case is probably explained by the presence of the 11-keto product, because it is known that hydrogenation of cortisone acetate in ethyl acetate with palladium on barium sulfate gives only a product of the allo series [7].

Djerassi and his co-workers [4] explained the preferential formation of a derivative of the pregnane series during hydrogenation of 11α-hydroxyprogesterone by the fact that the 11α-hydroxy group blocks the α-side of the steroid molecule, as a result of which, adsorption on the surface of the catalyst and introduction of hydrogen take place in the β-position. In this case, acetylation of the 11α-hydroxyl group must have increased the yield of the pregnane derivative; however, this was not observed by American authors. By carrying out the hydrogenation of 11α-acetoxyprogesterone in pyridine, we obtained a 93% yield of pure pregnanol-11α-dione-3,20 acetate. In another analogous experiment the whole of the crude hydrogenation product was saponified and the isomers were separated, as in the case of the hydrogenation of 11α-hydroxyprogesterone. We did not succeed in isolating the allo form. Therefore the hydrogenation of 11α-acetoxyprogesterone takes place in a more stereospecific manner than in the case of 11α-hydroxyprogesterone. Whereas hydrogenation of the tosylate of the latter under analogous conditions gives a 73.8% yield of allopregnanol-11α-dione-3,20 tosylate, the yield of the analogous product of the normal series is only 4%.

Therefore, other things being equal, pyridine is the factor which favors the formation of compounds of the normal series. At the same time, the character of the substituent in the 11-position of the steroid molecule is an immeasurably more important factor. However, the influence of the latter cannot be attributed simply to the blocking of the α-side of the steroid molecule, as is assumed by Djerassi and his co-workers. The problem of the stereospecificity of the hydrogenation of steroid Δ^4-3-keto unsaturated compounds requires further investigation.

EXPERIMENTAL*

Hydrogenation of 11α-hydroxyprogesterone. A quantity of 5 g of 11α-hydroxyprogesterone (m.p. 167-168° $[\alpha]_D^{20}$ + 178°) was dissolved in 22 ml of dry pyridine, purified by shaking with Raney nickel, and hydrogenated at room temperature and atmospheric pressure in the presence of 0.5 g of 10% palladium on calcium carbonate. After several hours, one mole of hydrogen was absorbed and reduction stopped. The catalyst was filtered off. The pyridine solution was added dropwise to a 1% aqueous solution of hydrochloric acid, cooled to 0°, and the hydrogenation product was extracted with chloroform. The chloroform extract was washed with dilute hydrochloric acid (1 : 4), water, an 8% solution of sodium bicarbonate and then with water again until a neutral reaction to litmus was obtained; it was then dried over magnesium sulfate. The solvent was distilled under vacuum. The residue was converted to the crystalline form by trituration with ether, and dried under vacuum at 50°. The yield was qualitative, the m.p. was 90-116°.

The product obtained was boiled for 30 minutes with a 5-fold volume of carbon tetrachloride and was left overnight at room temperature. The precipitate was filtered, washed with cold CCl$_4$, and ether, and dried under vacuum at 50°. We obtained 0.07 g (1.5%) of allo-pregnanol-11α-dione-3,20 (m.p. 185-192°). After recrystallization from ethyl acetate the m.p. was 197-199°, $[\alpha]_D^{20}$ + 82.84° (c 1, CHCl$_3$). Literature data give the m.p. as 194-196° [4]. The infrared spectrum contains 3450 and 1699 cm^{-1} bands.

After the separation of the allo compound the mother liquor was evaporated to dryness. We obtained 4.93 g of pregnanol-11α-dione-3,20. The latter was dissolved in 49 ml of acetone and oxidized with 10.5 ml of Kiliani's solution [8] at 25° for 10 minutes. The oxidation product was separated, the reaction mass being added dropwise to

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* The infrared spectra were obtained by means of IKS-14 apparatus with the crystalline substance in vaseline oil. Individual rotations were determined for 1% of the solutions.

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dilute sulfuric acid, cooled to 0°. The triketone was filtered, washed with water until a neutral reaction to litmus was obtained, and it was dried in a vacuum desiccator over sulfuric acid. We obtained 4.44 g (90%) of pregnantrione-3,11,20 (m.p. 143-146°).

The substance was dissolved in 8.9 ml of methylene chloride and 17.8 ml of ether was added. A quantity of 0.03 g (0.6%) of allo pregnantrione-3,11,20 (m.p. 211-215°) was deposited on standing. After recrystallization from ethyl acetate, the m.p. was 213-216°, $[\alpha]_D^{20}$ + 137.5° (c 1, CHCl$_3$). The infrared spectrum contains a 1705 cm^{-1} band. Literature data give: m.p. 212-216°, $[\alpha]_D^{20} \pm 133 + 2°$ (in anhydrous alcohol) [9]. The total yield of the allo form is 2.1%.

As a result of a number of experiments, 1.9 to 3.9 % of the allo compound was obtained. After the allo triketone had been separated, the mother liquor was evaporated to dryness and the residue was crystallized from a double volume of 50% alcohol. We obtained 3.13 g of pregnantrione-3,11,20 (63% calculated on the initial 11α-hydroxyprogesterone) with an m.p. of 153.5-154.5° and $[\alpha]_D^{20}$ + 119.8° (c 1, acetone). The infrared spectrum contains a 1699 cm^{-1} band, but the band of the free hydroxyl group is not present.

When the reduction of 11α-hydroxyprogesterone (5 g) was carried out in alcoholic solution (250 ml) with the same amount of catalyst (0.5 g of 10% Pd/CaCO$_3$) and with the addition of a solution of caustic potash in methanol (1 g of KOH in 15 ml of CH$_3$OH), a hydrogenated product (m.p. 156-183°) was obtained, containing 2.17 g of allo-pregnanol-11α-dione-3,20 (43.2%, separated by means of carbon tetrachloride, as described above), with an m.p. of 186-189°; after recrystallization, the m.p. was 197.5-199°, $[\alpha]_D^{20}$ + 89° (c 1, CHCl$_3$). We obtained 0.64% of allopregnantrione-3,11,20 (m.p. 210-213°) by oxidation of technical pregnanol-11α-dione-3,20.

The hydrogenation products were treated similarly in alcohol, dioxan and in dioxan in the presence of alkali.

Hydrogenation of 11α-acetoxyprogesterone. A quantity of 3 g of 11α-acetoxyprogesterone[m.p. 176.5-177.5°, $[\alpha]_D^{20}$ + 136.8° (CHCl$_3$), infrared spectrum: 1704 and 1728 cm^{-1}] was dissolved in 13.2 ml of pyridine and hydrogenated at room temperature and atmospheric pressure with 0.3 g of 10% Pd/CaCO$_3$. Hydrogenation was stopped after absorption of one mole of hydrogen. The catalyst was filtered, the pyridine solution was added dropwise to 1% hydrochloric acid cooled to 0°. The precipitate was filtered, washed with water and dried in a vacuum desiccator over sulfuric acid. We obtained 2.54 g (84.7%) of pregnanol-11α-dione-3,20 acetate with an m.p. of 149-150.5°. After recrystallization from a mixture of hexane and acetone, the m.p. was 152-153°, $[\alpha]_D^{20}$ + 63° (CHCl$_3$). The infrared spectrum contained 1714, 1731 and 1241 cm^{-1} bands. Literature data: m.p. 148-149°, $[\alpha]_D^{20}$ + 65° (CHCl$_3$) [4] and 152-153°, $[\alpha]_D^{20}$ + 63° (CHCl$_3$) [10].

The aqueous mother liquor was extracted with chloroform, and a further 0.37 g of the same product, with an m.p. of 151.5-153° (after recrystallization from a mixture of acetone and hexane) was obtained. The total yield of pregnanol-11α-dione was 93%. A mixed melt showed no depression of the melting point.

Hydrogenation of 11-ketoprognesterone. We dissolved 5 g of 11-ketoprognesterone[m.p. 173.5-174.5°, $[\alpha]_D^{20}$ + +232.7° (CHCl$_3$), the infrared spectrum contains 1699 and 1662 cm^{-1}] in 78 ml of pyridine; it was then hydrogenated at room temperature and atmospheric pressure with 0.5 g of 10% Pd/CaCO$_3$. After absorption of hydrogen had ceased the catalyst was filtered and the hydrogenated product was separated, as indicated above. The hydrogenated compound (m.p. 192-207°) was treated with a mixture of methylene chloride and ether (1 : 2). The insoluble residue was filtered, washed with a cold mixture of the solvents and dried. We obtained 3.79 g of allopregnantrione-3,11,20 (75.3%) with an m.p. of 210-214°. After recrystallization from ethyl acetate the m.p. was 216.5-218.5°, $[\alpha]_D^{20}$ + 137° (CHCl$_3$). The infrared spectrum contained a 1705 cm^{-1} absorption band, the band of the free hydroxyl group was not present. Literature data: m.p. 212-216°, $[\alpha]_D^{20}$ +133° [9].

The mother liquor (CH$_2$Cl$_2$ + ether) was concentrated to dryness, the residue was crystallized from 50% alcohol, and 0.87 g of pregnantrione-3,11,20 was obtained: m.p. 152.5-154° and $[\alpha]_D^{20}$ + 119.3° (acetone). A mixed melt showed no depression of the melting point. The infrared spectrum contained a 1701 cm^{-1} band. Literature data: m.p. 154-156°, $[\alpha]_D^{20}$ + 119.5° [11].

Hydrogenation of progesterone. 5 g of progesterone[m.p. 126-127°, $[\alpha]_D^{20}$ +193°(CHCl$_3$)]was hydrogenated in pyridine with 10% Pd/CaCO$_3$ under the conditions described for 11α-hydroxyprogesterone; the reduction product was separated in the same way as the latter. The substance obtained (m.p. 111-120°) was boiled with 21 ml of acetone until it had completely dissolved. The solution was cooled to 0° and after 2 hours the crystals were filtered, washed with cold acetone and dried. We obtained 2.4 g of a substance with an m.p. of 116.5-120.5°. It was re-

boiled for 30 minutes with 10 ml of acetone. The solution was cooled and left overnight at room temperature. The precipitate was filtered, washed with cold acetone and dried. We obtained 0.56 g (11.13%) of allopregnandione-3,20 (m.p. 194-197°). After recrystallization from alcohol the m.p. was 200.5-201.5° and $[\alpha]_D^{20}$ + 110.5° (CHCl$_3$). The infrared spectrum contained a 1712 cm^{-1} band. Literature data: m.p. 200-201°, $[\alpha]_D^{21}$ + 106 ± 4° [12].

After this 2.4 g of material had been separated, the mother liquor was concentrated to dryness and the residue was recrystallized from acetone. Pregnandione-3,20 with an m.p. of 120-121° and $[\alpha]_D^{20}$ + 113° (CHCl$_3$) was obtained. The infrared spectrum contained 1700 and 1719 cm^{-1} bands. Literature data: m.p. 120-122°, $[\alpha]_D$ + 111° [13].

After 0.56 g of allopregnandione-3,20 had been separated, the mother liquor was concentrated to dryness and the residue was recrystallized from acetone. Normal pregnandione-3,20 with an m.p. of 120.5-121.5° and $[\alpha]_D^{20}$ + +113° (CHCl$_3$) was obtained. The infrared spectrum contained 1700 and 1719 cm^{-1} bands.

The total yield of normal pregnandione-3,20 was 4 g (79.9%).

Hydrogenation of 11α-hydroxyprogesterone tosylate. 11α-hydroxyprogesterone tosylate was obtained by the method of Rosenkranz and his co-workers [14] [m.p. 153-154°, $[\alpha]_D^{20}$ + 127° (CHCl$_3$), 1701 and 1669 cm^{-1} bands in the infrared spectrum]. We dissolved 3 g of the substance in 13 ml of pyridine and it was hydrogenated with 0.3 g of 10% Pd/CaCO$_3$. The hydrogenated product was separated by decanting into ice water (2.36 liters at 0°). The precipitate was filtered, washed with water, dissolved in a mixture of ether and chloroform (4 : 1) and the solution was dried with calcined MgSO$_4$. The solvent was distilled under vacuum and the residue was thoroughly dried. We obtained 2.98 g of material with an m.p. of 138-139°. The aqueous mother liquor was treated with chloroform and a further 0.02 g of material was separated.

The tosylate obtained was boiled for 30 minutes with carbon tetrachloride (14.9 ml)* and left to stand overnight at room temperature. The precipitate was filtered, washed with cold carbon tetrachloride, and ether, and dried under vacuum. We obtained 2.08 g (69.1%) of material with an m.p. of 138-139°. It was recrystallized from ethanol, isopropyl alcohol, ethyl acetate and a mixture of acetone and benzene (2 : 1); the m.p. was 139.5-141.5°, $[\alpha]_D^{20}$ +74.36° (CHCl$_3$). The infrared spectrum contained 1701 and 1713 cm^{-1} bands, but the band for the free hydroxyl group was not present.

Found %: C 69.38; H 7.65; S 6.53. C$_{28}$H$_{38}$O$_5$S. Calculated %: C 69.1; H 7.87; S 6.58.

A mixed sample with material obtained by tosylation of allopregnanol-11α-dione-3,20 showed no depression of the melting point.

The mother liquor from the allotosylate was concentrated to dryness, and 0.87 g of a substance with an m.p. of 130-131° was obtained. It was dissolved in alcohol and boiled with activated charcoal. The solution was filtered, the solvent was distilled under vacuum, the residue was ground with ether and cooled. The residue was filtered, washed with cold ether and dried. We obtained 0.39 g of a product with an m.p. of 134-135.5°. This product was again treated with carbon tetrachloride (1 : 5) while boiling. After it had cooled, we obtained 0.17 g of a substance with an m.p. of 138.5-141°. After it had been recrystallized from isopropyl alcohol we obtained 0.14 g (4.65%) of tosylate with an m.p. of 139.5-141.5°. A mixed melt with the tosylate of allopregnanol-11 α-dione-3,20 showed no depression of the melting point. The total yield of this compound was 73.7%.

All the mother liquors were concentrated to dryness. We obtained 0.7 g of a product with an m.p. of 112-117°, which was dissolved in isopropyl alcohol while boiling and was treated with activated charcoal. After the charcoal had been removed on the filter the solvent was distilled under vacuum until crystallization commenced. We obtained 0.36 g of a substance with an m.p. of 135-138°; after this had been recrystallized 6 times from isopropyl alcohol we obtained 0.121 g (4.02%) of the tosylate of pregnanol-11α-dione-3,20 with an m.p. of 153.5-154.5° and $[\alpha]_D^{20}$ + 77.1° (CHCl$_3$). The infrared spectrum contains a 1709 cm^{-1} band, the free hydroxyl group band is absent. Literature data : m.p. 156-157°, $[\alpha]_D^{25}$ + 77.1° [15].

Found %: C 69.15; H 7.85; S 6.41. C$_{28}$H$_{38}$O$_5$S. Calculated %: C 69.1; H 7.87; S 6.58.

A mixed melt showed no depression of the melting point.

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* Pure allopregnanol-11α-dione-3,20 tosylate is difficultly soluble in carbon tetrachloride (solubility at room temperature 1 : 500), pregnanol-11α-dione-3,20 tosylate is more soluble (1 : 80).

Preparation of allopregnanol-11α-dione-3,20 tosylate. We dissolved 2.4 g of allopregnanol-11α-dione-3,20 [m.p. 197-199°, $[\alpha]_D^{20}$ +82.84° (CHCl₃)]in 8.4 ml of pyridine and the solution was cooled to 0°. A quantity of 1.39 g of p-toluenesulfonyl chloride was added with fairly vigorous stirring to the pyridine solution. The reaction mass was stirred for 1 hour and left at room temperature for 3 days. The allotosylate was precipitated by adding the pyridine solution to cooled (0°) water. The precipitate was filtered, washed with water and dissolved in a mixture of ether and chloroform (2 : 1). The solution obtained was washed with dilute hydrochloric acid, water, a solution of sodium bicarbonate and water until a neutral reaction to litmus was obtained. The solvent was distilled under vacuum at a temperature up to 50°. The residue (2.84 g, m.p. 133.5-137°) was boiled with carbon tetrachloride (14 ml), cooled and left overnight at room temperature. The precipitate was filtered, washed with carbon tetrachloride and dried. We obtained 2.73 g of material with an m.p. of 139.5-141.5°. After this had been recrystallized from a mixture of acetone and hexane (2 : 1) and then from ethyl acetate, the m.p. was 139.5-141°, $[\alpha]_D^{20}$ + +74° (CHCl₃). The infrared spectrum contained 1700 and 1712 cm⁻¹ bands.

SUMMARY

1. The hydrogenation of 11α-hydroxyprogesterone with 10% palladium on calcium carbonate at room temperature and atmospheric pressure was investigated in various solvents. It was shown that pyridine ensures the greatest stereospecificity.

2. It was established that in contract to hydrogenation in alcohol, hydrogenation of progesterone in pyridine gives mainly a product of the normal series.

3. It was shown that although, other things being equal, pyridine ensures a predominance of the normal-series hydrogenation product in the progesterone series and its 11-substituents, the decisive role is played by the substituent in the 11-position. Whereas hydrogenation of 11α-acetoxyprogesterone in pyridine gives only the pregnane derivative, 11-ketoprogesterone and 11α-hydroxyprogesterone tosylate give principally compounds of the allo series.

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ACYL DERIVATIVES OF BARBITURATES, HEXAMIDINE
AND DIPHENYL HYDRANTOIN

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It was previously reported [1] that introduction of a benzoyl group into the luminal molecule is accompanied by a considerable heightening of the antispastic effect and a reduction in the hypnotic and toxic effect of this barbiturate.

It was of interest to obtain acyl derivatives of other barbiturates, and also of diphenin and hexamidine [2], known for their comparatively high antispastic activity.

The acyl derivatives were obtained by the action of acyl chlorides of carboxylic acids on the sodium salts of the initial substances or on the initial substances in the presence of pyridine. All the compounds described below are crystalline products, insoluble in water but fairly soluble in acetone, alcohol and benzene.

According to the preliminary results of E. M. Dumenova (Department of Pharmacology, Tomsk Medical Institute), the introduction of one benzoyl group into a molecule of veronal, barbamyl or hexenal leads to the same results as in the case of luminal, i.e., to an increase in the antispastic effect and a reduction in the toxicity of the barbiturate, whereas benzoylation of diphenyl hydantoin and hexamidine does not have an appreciable effect on 'he physiological properties of these compounds.
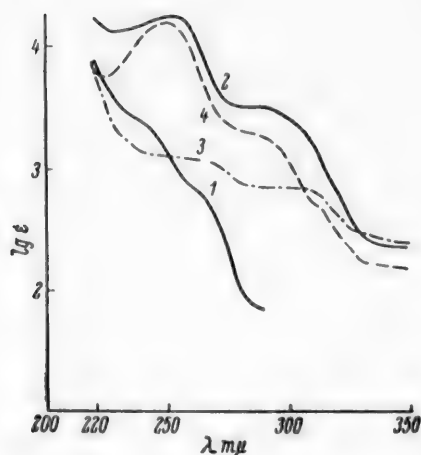
Fig. 1. Ultraviolet absorption spectra: 1) Luminal; 2) di-(acetylsalicyl)-luminal; 3) veronal; 4) benzoylveronal.
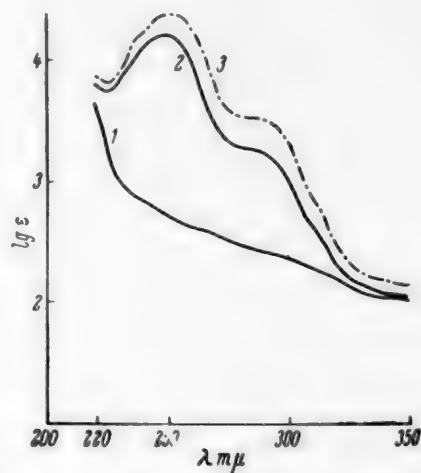
Fig. 2. Ultraviolet absorption spectra: 1) 5-ethyl-5-isoamylbarbituric acid; 2) 5-ethyl-5-isoamyl-3-benzoylbarbituric acid; 3) 5-ethyl-5-isoamyldibenzoylbarbituric acid.
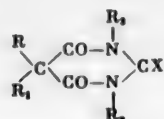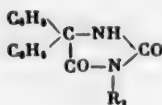
(I)—(VI), (VIII)   (VII)

No. of compound	X	R	R_1	R_2	R_3	λ_{max} (in mμ)	lg ε_{max}
(I)	O	C_2H_5	C_2H_5	C_6H_5CO	H	250	4.1931
(II)	O	C_6H_9	CH_3	C_6H_5CO	CH_3	250	4.066
(III)	O	C_6H_9	CH_3	CH_3CO	CH_3	—	—
(IV)	O	C_2H_5	iso-C_5H_{11}	C_6H_5CO	H	250	4.2076
(V)	O	C_2H_5	iso-C_5H_{11}	C_6H_5CO	C_6H_5CO	250	4.3927
(VI)	O	C_2H_5	C_6H_5	$C_6H_4(OCOCH_3)CO$	$C_6H_4(OCOCH_3)CO$	252	4.2495
(VII)	—	—	—	C_6H_5CO	—	253	4.1498
(VIII)	H_2	C_2H_5	C_6H_5	C_6H_5CO	H	250	4.0000

The introduction of a second acyl group is accompanied by a reduction in the physiological activity of the barbiturate.

The antispastic effect of monobenzoyl derivatives of luminal and hexamidine is approximately the same; benzoyldiphenyl hydantoin is far inferior to them in this respect.

The absorption spectra in the ultraviolet region were determined for all the initial compounds and their acyl derivatives in an SF-4 spectrophotometer (Figs. 1-4). The solvent used was 96% alcohol.

Acylation of a heterocyclic compound leads to the appearance of a strong absorption band with a mximum at 250 mμ in the spectrum; a second acyl group increases the intensity of absorption without changing the position of the maximum. The characteristic absorption bands and the corresponding molecular extinction coefficient are given in the table.
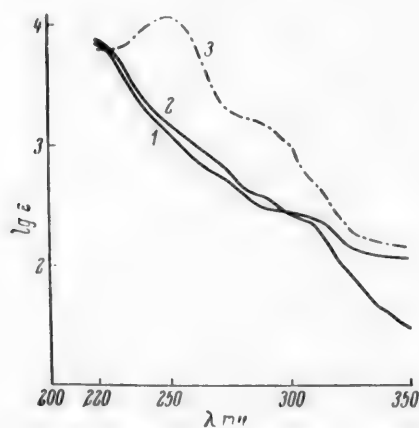
Fig. 3. Ultraviolet absorption spectra. 1) 5-cyclohexenyl-1,5-dimethylbarbituric acid; 2) 5-cyclohexenyl-1,5-dimethyl-3-acetylbarbituric acid; 3) 5-cyclohexenyl-1,5-dimethyl- 3-benzoyl-barbituric acid.
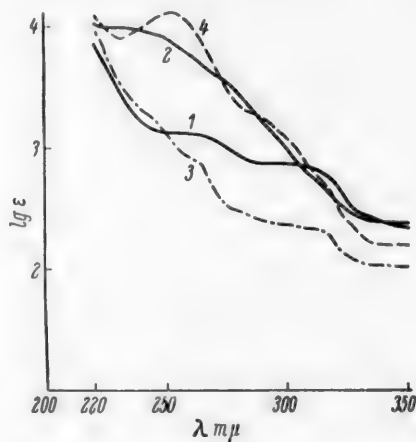
Fig. 4. Ultraviolet absorption spectra. 1)Hexamidine; 2) benzoyl hexamidine; 3) diphenyl hydantoin; 4) benzoyl diphenyl hydantoin.

EXPERIMENTAL

Benzoyl veronal (I). A mixture of 9.2 g of veronal, 5.7 ml of benzoyl chloride and 4 ml of pyridine was heated with stirring on an oil bath for 2 hours at 150-155°. When the reaction had finished, the mass was treated with 50 ml of benzene with heating; it was then cooled, the liquid was decanted and the solid residue was washed with water, dried and recrystallized from alcohol. The product was obtained as white crystals with an m.p. of 163-164°.

Found %: N 9.66. $C_{15}H_{16}O_4N_2$. Calculated %: N 9.72.

5-Cyclohexenyl-1,5-dimethyl-3-benzoyl barbituric acid (II). A quantity of 10 g of hexenal and 4.4 ml of benzoyl chloride were heated at 110-115° with stirring on an oil bath for 4 hours. The reaction mixture was cooled, treated with acetone and filtered; the acetone was distilled and the sirupy residue was washed with ice water until it solidified. The crystallized mass was filtered and washed again with cold water on the filter; it was then dried and recrystallized from alcohol. The product was obtained as white crystals with an m.p. of 106-107°.

Found %: N 8.13, 8.10. $C_{19}H_{20}O_4N_2$. Calculated %: N 8.23.

5-Cyclohexenyl-1,5-dimethyl-3-acetylbarbituric acid (III). This was obtained in a similar way to (II), from 4.82 g of hexenal and 1.3 ml of acetyl chloride. The product was obtained as intermingling needles with an m.p. of 96-97°.

Found %: N 10.4. $C_{14}H_{18}O_4N_2$. Calculated %: N 10.07.

5-Ethyl-5-isoamyl-3-benzoyl barbituric acid (IV). This was obtained in a similar way to (I), from 9.04 g of ethylisoamyl barbituric acid, 4.6 ml of benzoyl chloride and 3.3 ml of pyridine with heating to 110-115° on an oil bath (4 hours). After the reaction product had been extracted with benzene the solvent was distilled, and the residual sticky viscous mass was treated with ice water until it solidified. It was dissolved in the minimum amount of alcohol (25-30 ml), filtered and precipitated with water. The product was obtained as fine needles with an m.p. of 112-113°.

Found %: N 8.23, 8.25. $C_{18}H_{22}O_4N_2$. Calculated %: N 8.48.

5-Ethyl-5-isoamyl-1,3-dibenzoyl barbituric acid (V). This was obtained simultaneously with the monobenzoyl derivative of (IV). It was easily separated from the latter by recrystallization because it is far less soluble in cold alcohol. It was obtained as fine crystals with an m.p. of 148-149°.

Found %: N 6.59. $C_{25}H_{26}O_5N_2$. Calculated %: N 6.45.

Di-(acetylsalicyl)-luminal (VI). This was obtained in a similar way to (II) from 6.3 g of the sodium salt of luminal and 4.9 g of the acyl chloride of aspirin. White needles with an m.p. of 158-159°.

Found %: N 5.00, 4.93. $C_{30}H_{24}O_9N_2$. Calculated %: N 5.03.

Benzoyl diphenyl hydantoin (VII). This was obtained in a similar way to (I) from 5.04 g of diphenyl hydantoin, 2.3 ml of benzoyl chloride and 1.6 ml of pyridine with heating on an oil bath (110-115°) for 2 hours. White crystals with an m.p. of 162-163°.

Found %: N 7.97. $C_{22}H_{16}O_3N_2$. Calculated %: N 7.83.

Benzoyl hexamidine (VIII). This was obtained in a similar way to (I) from 2.2 g of hexamidine, 0.8 ml of pyridine and 1.2 ml of benzoyl chloride with heating on an oil bath (140-145°) for 5 hours. The reaction product was extracted with benzene with heating and the precipitate which came out on cooling was filtered and recrystallized from alcohol. Colorless plates with an m.p. of 187-189°.

Found %: N 8.89, 8.75. $C_{19}H_{18}O_3N_2$. Calculated %: N 8.69.

SUMMARY

1. The acyl derivatives of veronal, hexenal, barbamyl, diphenyl hydantoin and hexamidine were obtained. The ultraviolet absorption spectra of the compounds obtained were determined and their pharmacologic activity was estimated.

2. It was established that the introduction of a benzoyl group into the nitrogen of a heterocyclic compound increases the antispastic activity of barbiturates but does not have an appreciable effect on the physiological properties of diphenyl hydantoin and hexamidine.

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THE AUTOXIDATION OF STROPHANTHIDIN

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If a methanolic solution of strophanthidin or its glucosides is left in an open vessel for one or two days, on the paper chromatogram of such a solution, in addition to the spot of the main substance the spot of an unidentified compound appears. If the solution is allowed to stand for a further period the spot of the new compound on the chromatogram is steadily intensified, whereas that of the initial substance becomes weaker and after a certain period disappears altogether. Similar observations were made in the case of certain strophanthidin derivatives, particularly for tetra-O-acetyl-strophanthidin-β-d-glucoside [1] and corchoroside A (strophanthidin-β-d-boivinoside) [2].

Those who observed this phenomenon assumed of course that it was due to the oxidation of the aldehydic group of aglucone. This capacity to undergo oxidation by atmospheric oxidation is also inherent in certain other genins with an aldehydic group in the 19 position, particularly corotoxigenin [3, 4], bovogenin A [5] and calotro-pagenin [6]. On the basis of the fact that in these three genins the A and B rings are joined in the trans position, Geiger and his co-workers [6] suggested that this is the basic condition for such oxidation. There are no direct literature data on the nature of the endproduct of the autoxidation of strophanthidin, in the molecule of which the A and B rings are coupled in the cis position and where there is also an additional OH group in the 5 position.

We investigated the autoxidation product of strophanthidin. For this purpose we passed a current of oxygen through a methanolic solution of strophanthidin (IV, R = CHO). The oxidation process evidently began immediately, because within a short time a spot of a new compound, more polar than strophanthidin (band 2 in figure), had al-

(I) R = CHO,
(II) R = COOH,
(III) R = COOCH₃.

(IV) R = CHO,
(V) R = COOH,
(VI) R = COOCH₃,
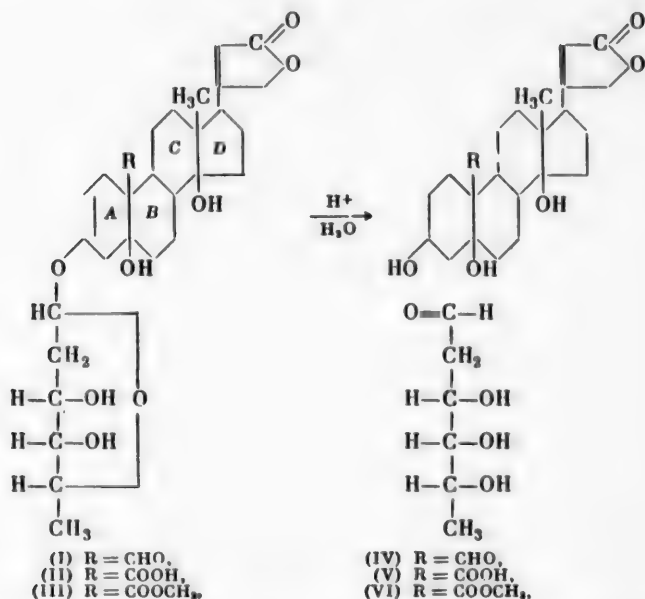
ready appeared on the paper chromatogram. After 45 hours the reaction was interrupted and the unreacted strophanthidin was separated. The reaction product (45% yield) was an acid, identical with strophanthidinic acid (V, R = COOH) [7]. When converting calotropin to calotaxin, Geiger and his co-workers [6] noted that the oxidation

process was markedly accelerated by irradiation with ultrashort waves. In our experiments with strophanthidin the quartz glass reaction vessel was irradiated with ultraviolet light. However, we did not observe an appreciable acceleration of the process during such irradiation or during heating. To confirm the inertness of the solvent during the autoxidation process, a solution of strophanthidin in methanol was kept in an atmosphere of nitrogen in a sealed container for 2 years. The initial strophanthidin was found to be unchanged.

The autoxidation of helveticoside [8] (desglucoerisimoside [9]) (I, R = CHO) by atmospheric oxygen took place similarly. Here, the oxidation process was carried to completion. For this purpose a methanolic solution of the glucoside was kept in an open vessel for 67 days, i.e., until the spot of the initial compound (band 8 in figure) on the paper chromatogram had disappeared. Oxidation is clearly accompanied by hydrolysis, because the spot of helveticosidic acid (II, R = COOH) on the paper chromatogram is accompanied by the spot of strophanthidinic acid. The helveticosidic (desglucoerisimosidic) acid we obtained was not crystalline. In contrast to cymarilic acid [10], its methyl ester (III, R = COOCH$_3$) was also amorphous. To confirm that autoxidation of the glucone part took place in this case, helveticosidic acid and its methyl ester were subjected to mild acid hydrolysis. As might be expected, during this process strophanthidinic acid (V) and its methyl ester (VI) were formed.

Oxidation of the aldehyde group to a carboxyl group leads to a marked reduction in the biologic activity of the glucoside.[*] When tested on white mice (the material was introduced subcutaneously) the mean lethal dose of helveticoside was 8.3 mg/kg, whereas the lethal dose for helveticosidic acid was 71.2 mg/kg. During investigations on isolated frogs' hearts, the helveticosidic acid concentration required for systolic arrest of the heart was 70-120 fold greater than the helveticoside concentration. These facts are similar to those observed by Blome and Reichstein [10] in the case of cymarin and cymarilic acid.

EXPERIMENTAL

Figure shows control paper chromatograms of derivatives of strophanthidin (A) and helveticoside (B). This figure also gives comparative paper chromatograms of strophanthidin, helveticoside and the methyl esters of these acids (C). A quantity of 0.02-0.03 mg of the substance was added to the paper. In all cases the developer was Raymond's reagent.
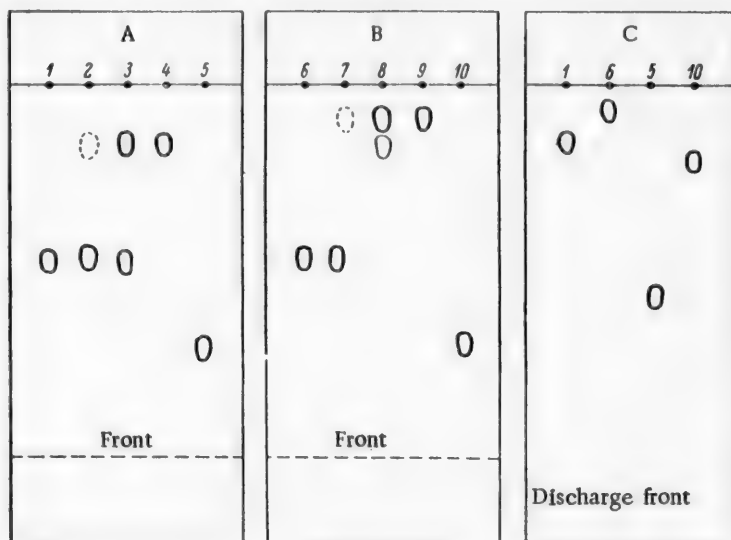
Control paper chromatograms. For chromatograms A and B) System ethanol-chloroform (1 : 9)—formamide, 2.5 hours, 19°; for chromatogram C) system toluene-chloroform (1 : 1)—formamide, 12 hours, 20°: 1) Strophanthidin (freshly prepared solution in methanol); 2) the same solution after oxygen had been passed for 6 hours; 3) the same solution after oxygen had been passed for 45 hours; 4) strophanthidinic acid; 5) methyl ester of strophanthidinic acid; 6) helveticoside; 7) solution of helveticoside after 2 days; 8) the same solution after 67 days; 9) helveticosidic acid; 10) methyl ester of helveticosidic acid.

[*] The biologic investigation was carried out by N. A. Kambulin, A. K. Kompantseva, and D. E. Tuniyants.

The strophanthidinic acid required for the comparison was obtained by Jacobs' method [7] by the oxidation of 400 mg of strophanthidin (in 16 ml of acetone) with 112 mg of potassium permanganate. The yield was 140 mg. After recrystallization from a dilute standard the acid had an m.p. of 181-183°.

Autoxidation of strophanthidin to strophanthidinic acid. Oxygen was passed through a solution of 700 mg of strophanthidin in 30 ml of methanol at a rate of 50 ml per minute for 45 hours. The methanolic solution was then evaporated to dryness under vacuum. The dry residue was dissolved in 20 ml of 0.5 N ammonia. The insoluble part was separated and the solution was acidified with acetic acid. The acid precipitated (315 mg) as a result of this was recrystallized from a mixture of ethanol and water. We obtained 150 mg of a crystalline substance with an m.p. of 179-182°, $[\alpha]_D^{28} + 52.3 \pm 2°$ (c 1.15, methanol). A mixed sample with known strophanthidinic acid showed no depression of the melting point. The color reaction with 84% H_2SO_4 with respect to time was as follows: 0 minutes—colorless, 5 minutes—yellow, 15 minutes—orange, 30 minutes—orange, 1 hour—light-orange, 2 hours—colorless.

Found %: C 63.83, 63.90; H 7.51, 7.61. $C_{23}H_{32}O_7 \cdot 0.5H_2O$. Calculated %: C 64.32; H 7.74.

Literature data for strophanthidinic acid: m.p. 185-190° (for the semihydrate), $[\alpha]_D + 54.8°$ (methanol) [7]; agglomerates at 175°, melts at 185°, $[\alpha]_D^{20} + 53.8 \pm 1°$ (methanol) [11]; m.p. 174-177°, $[\alpha]_D^{25} \pm 2°$ (methanol) [12].

Autoxidation of helveticoside to helveticosidic acid. A quantity of 900 mg of helveticoside was dissolved in 50 ml of methanol and left to stand at room temperature in an open flask under conditions which did not prevent free access of air. The course of spontaneous oxidation was checked by analysis of samples of the solution on chromatographic paper. On the 67th day the spot of the initial compound on the chromatogram had disappeared, after which the methanolic solution was evaporated to dryness under vacuum. The residue contained a light-colored mass which readily crumbled to powder. The acid obtained was purified by repeated reprecipitation from water, after which it had an m.p. of 132-133°, $[\alpha]_D^{20} + 40.8 \pm 1.5°$ (c 2.18, ethanol). Helveticosidic acid was difficulty soluble in cold and hot water, and readily soluble in methanol, ethanol and acetone. Attempts to recrystallize the acid from these solvents or mixtures of them with water or ether were unsuccessful. Crystalline salts could also not be obtained with alkalis. The Keller-Kiliani reaction and the Frerjaque-Durje reaction (with a solution of vanilin and phosphoric acid in alcohol) were positive. The color reaction with 84% H_2SO_4 with respect to time was as follows: 0 minutes—brown, 5, 15 and 30 minutes—dark-brown, 2 hours—chestnut-brown.

Before analysis the substance was dried under vacuum above P_2O_5 at 105° to constant weight.

Found %: C 62.83, 63.02; H 7.69, 7.59. $C_{29}H_{42}O_{10}$. Calculated %: C 63.26; H 7.69.

Methyl ester of helveticosidic acid. A quantity of 200 mg of helveticosidic acid (in the form of a fine powder) was suspended in 15 ml of dry ether, to which 2 ml of an ethereal solution of diazomethane was added in portions. After 3 hours, when the initially vigorous reaction had somewhat abated, a further 2 ml of diazomethane solution was added; the reaction vessel was then left to stand at room temperature. After two days the ether was distilled and the residue was ground to powder. We did not succeed in obtaining the methyl ester of helveticosidic acid in a crystalline form. After the ester obtained had been dried under vacuum at room temperature over phosphorus pentoxide it melted in a wide range (94-122°), $[\alpha]_D^{19} +36.3 \pm 1°$ (c 2.29, ethanol). Like strophanthidin and helveticoside [9], the methyl ester of helveticosidic acid is displaced simultaneously with the methyl ester of strophanthidinic acid in the systems toluene-butanol (1:1) - water and ethanol - chloroform (1:9) - formamide. To distinguish these esters it is best to employ the system: toluene - chloroform (1:1) - formamide (see Fig. 1, C). The color reactions were similar to the reactions of helveticosidic acid.

Found %: C 61.18, 61.17; H 8.09, 8.00. $C_{30}H_{44}O_{10} \cdot H_2O$. Calculated %: C 61.84; H 7.96.

Hydrolysis of helveticosidic acid. A quantity of 200 mg of helveticosidic acid in 15 ml of methanol was heated at 80-85° for 25 minutes after the addition of 10 ml of 0.1 N sulfuric acid. The methanol was distilled under vacuum. The precipitate (105 mg) from the aqueous solution was recrystallized from ethanol and water. After they had been dried at 110° the crystals had an m.p. of 175-176°, $[\alpha]_D^{20} + 52.2 \pm 2°$ (c 1.25, methanol); a mixed sample with strophanthidinic acid showed no depression of the melting point. The Keller-Kiliani and Frerjaque-Durje reactions were negative. The color reactions with 84% H_2SO_4 were similar to those of strophanthidinic acid.

Found %: C 64.05; H 7.61. $C_{23}H_{32}O_7 \cdot 0.5H_2O$. Calculated %: C 64.32; H 7.74.

Hydrolysis of the methyl ester of helveticosidic acid. A quantity of 114 mg of the methyl ester of helveticosidic acid in 5 ml of ethanol was mixed with 5 ml of 0.1 N sulfuric acid and heated on a water bath for 15 minutes. After the ethanol had been distilled, a precipitate (57 mg) was deposited from the solution. By recrystallization of the precipitate from water and ethanol, crystals in the form of short prisms were obtained; after these had been dried under vacuum at 110°, they agglomerated at 144° and melted with frothing at 148-150°, $[\alpha]_D^{21}$ +57.4 ± 3° (c 0.76, methanol). The Keller-Kiliani and Frerjaque-Durje color reactions were negative. The color reaction with 84% H_2SO_4 with respect to time was as follows: 0 minutes—colorless, 5 minutes—yellow, 15 minutes—orange, 30 minutes—rose, 1 hour — colorless.

Found %: C 63.76, 63.83; H 8.09, 7.94; OCH_3 6.71, 6.73. $C_{24}H_{34}O_7 \cdot H_2O$. Calculated %: C 63.70; H 8.02; OCH_3 6.86.

Literature data for the methyl ester of strophanthidinic acid: agglomerates at 150° and melts at 160-163°, $[\alpha]_D^{27}$ +57.6° (methanol) [7]; m.p. 144-147°, $[\alpha]_D^{19}$ +57.1 ± 2° (methanol) [11].

SUMMARY

The autoxidation products of strophanthidin and helveticoside were investigated. In both cases, autoxidation was due to oxidation of the carbonyl group in the 19 position to a carboxyl group. By way of example of strophanthidin it was shown that cis-coupling of the A and B rings does not prevent the phenomenon of autoxidation.

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XANTHOTOXIN FROM THE FRUITS OF THE CULTIVATED PARSNIP

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Our previous investigations of fruits of the cultivated parsnip (Pastinaca sativa L.) [1, 2] showed that in them occurs a whole complex of furocoumarin compounds, consisting of seven components. Four of the seven components were identified with previously known furocoumarins: imperatorin , bergapten , xanthotoxol, and isopimpinellin , while the remaining three substances were not completely characterized. Continuing the study of the chemical composition of these compounds, we came to the conclusion that substance B obtained previously [2] is xanthotoxin. That substance B and xanthotoxin are identical was proved by preparation and comparison of a series of their derivatives, and also by the partial synthesis of B from imperatorin.
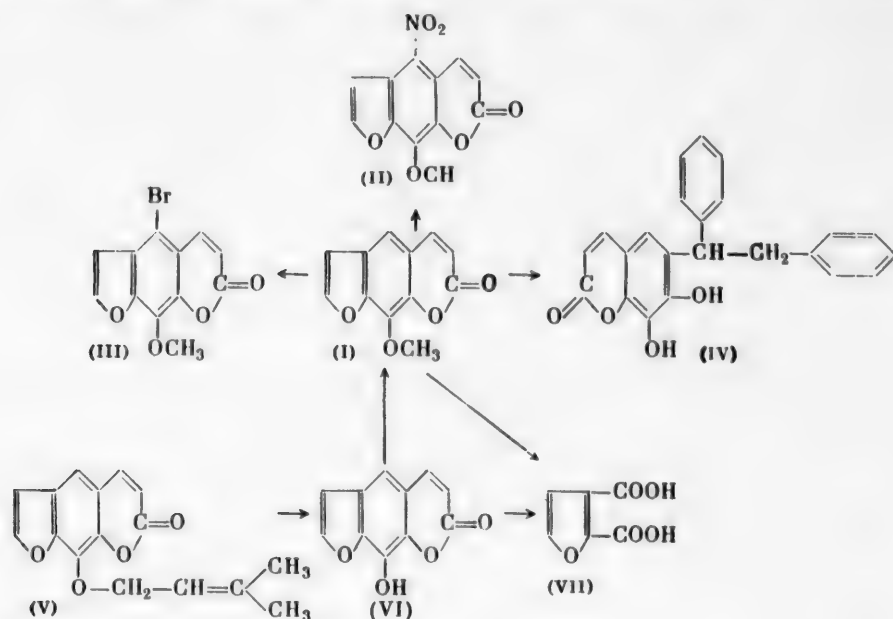
(I)−xanthotoxin (9-methoxypsoralen);

(II)−9-methoxy-4-nitropsoralene;

(III)−9-methoxy-4-bromopsoralen ;

(IV)−6-(1,2-diphenylethyl)-7,8-dihydroxycoumarin;

(V) −imperatorin;

(VI)−xanthotoxol;

(VII)−furan-2,3-dicarboxylic acid.

The nitro- and bromoderivatives of substance B obtained are completely identical to nitroxanthotoxin (II) and bromoxanthotin (III); on reacting substance B with AlCl$_3$ in benzene, opening of the furan ring occurs with formation of a compound identical to 6-(1,2-diphenylethyl)-7,8-dihydroxycoumarin (IV). Acid hydrolysis of imperatorin (V) leads to the preparation of a free phenolic furocoumarin−xanthotoxol (VI), methylation of which with dimethyl sulfate leads to the preparation of xanthotoxin (I). The substance obtained as a result of semisynthesis of xanthotoxin appeared completely identical to substance B, obtained from parsnip fruits.

During investigation of the furocoumarin composition of cultivated parsnip fruits, it was established that content of xanthotoxin and several other substances varies, depending on the type of parsnip. Thus, type "Gernseiskii" is the richest in xanthotoxin content, this reaching 0.1% of seed weight. Xanthotoxin content is considerably lower in other types.

Xanthotoxin was first prepared from Fagara zanthoxyloides Lam. [3], and its structure soon established [4, 5]. In latter years, interest in xanthotoxin has increased considerably owing to the observation in it of a medicinal effect toward leucodermia [6, 7]. It has also been established that its external application with subsequent irradiation with ultraviolet light increases the receptivity of the skin to the rays and brings about its darkening [8-10]. In the literature [11, 12] there are also indications of the dependence of the photosensitizing effect on the chemical structure of the furocoumarins, derivatives of psoralen, xanthotoxin, and bergapten. Preparations containing xanthotoxin find practical usage in treatment of leucodermia (vitiligo) [13].

EXPERIMENTAL

Preparation of substance B (xanthotoxin) from fruits of cultivated parsnip. 5 kg of the fruits of the cultivated parsnip, type "Gernseikil," were crushed and extracted twice with ethanol. Ethanol was evaporated from the extracts, the residue dissolved in 1 liter of chloroform, the solution diluted with 4 times its volume of petroleum ether and chromatographed on a column of 2 kg of neutral alumina of third group activity. Eluation of the substances adsorbed on the column was carried out initially with a solvent mixture of the same composition; oils and imperatorin passed into the eluate at this stage. The yellow zone, containing a mixture of bergapten , substance B (xanthotoxin), and isopimpinellin was then eluated with a mixture of chloroform and petroleum ether in the proportion 1 : 3. The eluate, containing a mixture of furocoumarin substances, was evaporated to a volume of 500 ml, and from this concentrate a mixture of substance B and bergaptene crystallized. The resulting acicular crystals were filtered off, washed with petroleum ether and dried. Yield of crystalline product amounted to 12.4 g. The crystals were dissolved by heating in 150 ml of benzene; on cooling the solution, crystals of bergapten were obtained from this solution as long, silky needles. These were filtered off, the mother liquor concentrated to a volume of 30-40 ml, crystals of substance B (xanthotoxin) then being obtained. The crystals were separated and recrystallized from hot alcohol. Yield of substance B amounted to 5.2 g. M.p. 145-147°. The crystals readily dissolved in chloroform, hot alcohol, benzene, with greater difficulty in cold alcohol, ether, and with extreme difficulty in water.

Found %: C 66.78; H 3.64. $C_{12}H_8O_4$. Calculated %: C 66.67; H 3.73.

9-Methoxy-4-nitropsoralene (II). 2 g of substance B (xanthotoxin) was dissolved in 20 ml of glacial acetic acid at 20° and 16 ml of concentrated HNO_3 added with slight stirring. After a few seconds the mixture became dark-red, and a solid precipitate gradually began to separate from it. This product was poured with stirring into 40 ml of ice water, the solution filtered, the precipitate washed with cold water and dried. The product obtained was recrystallized from alcohol. A yellow substance was obtained with m.p. 235-237°. Yield 1.94 g.

Found %: C 55.36; H 2.78. $C_{12}H_7O_6N$. Calculated %: C 55.15; H 2.79.

9-Methoxy-4-bromopsoralene (III). 1 g of substance B (xanthotoxin) was dissolved in 20 ml of chloroform, 1 mole of bromine in chloroform added to the solution and stirred well. After 10-15 minutes the solvent was removed on a water bath and the residue crystallized from alcohol. Yield of crystalline bromoderivative amounted to 1.16 g. M.p. 185-186°. A sample mixed with 9-methoxy-4-bromopsoralen obtained from semisynthetic xanthotoxin gave no melting point depression.

Found %: C 48.78; H 2.43. $C_{12}H_7O_4Br$. Calculated %: C 48.8; H 2.38.

6-(1,2-Diphenylethyl)-7,8-dihydroxycoumarin (IV). 1 g of substance B (xanthotoxin) and 2 g of $AlCl_3$ were placed in a round-bottomed flask and heated for 30 minutes with 100 ml of benzene with reflux condenser. The benzene solution was decanted and the solvent evaporated to dryness. The residue was neutralized with acid and crystallized from dilute alcohol. 0.82 g of a white, crystalline substance was obtained with m.p. 241-243°. A sample mixed with 6-(1,2-diphenylethyl)-7,8-dihydroxycoumarin obtained from semisynthetic xanthotoxin gave no melting point depression.

Found %: C 74.92; H 4.70. $C_{23}H_{18}O_4$. Calculated %: C 75.20; H 4.90.

Acid hydrolysis of imperatorin (V). 100 g of imperatorin was dissolved in 1 liter of glacial acetic acid, and 3 ml of concentrated sulfuric acid added to the solution. The mixture was left to stand at room temperature for

18 hours. The crystals obtained were filtered off, washed with acetic acid and dried. The substance was recrystallized from ether. Yield 62 g, m.p. 242-244°. The crystals dissolved readily in alkali and with great difficulty in organic solvents and water. A sample mixed with an authentic sample of xanthotoxol gave no melting point depression.

Found %: C 64.82; H 2.97. $C_{11}H_6O_4$. Calculated %: C 64.87; H 3.09.

Semisynthesis of xanthotoxin (I). A. 5 g of xanthotoxol was suspended in 500 ml of chloroform and diazotized with diazomethane in the cold for 40 minutes. Chloroform was evaporated off, and the residue crystallized from alcohol. Colorless, silky needles were obtained with m.p. 145-147°. A sample mixed with substance B gave no melting point depression. Yield of xanthotoxin 5.2 g.

Found %: C 66.70; H 3.65; OCH_3 13.5. $C_{12}H_8O_4$. Calculated %: C 66.67; H 3.70; OCH_3 12.6.

B. 20 g of xanthotoxol was dissolved in 2 liters of aqueous sodium carbonate solution and 1 mole of dimethyl sulfate added with continuous stirring. The resulting flocculent powder was filtered off, washed with water, dried and recrystallized from alcohol. M.p. 145-147°. Yield 21.2 g. A sample of the product mixed with an authentic sample of xanthotoxin gave no melting point depression.

Found %: C 66.72; H 3.68; OCH_3 13.7. $C_{12}H_8O_4$. Calculated %: C 66.67; H 3.70; OCH_3 12.6.

Furan-2,3-dicarboxylic acid (VII). 1 g of xanthotoxin (I) was dissolved by heating in 80 ml of 5% NaOH solution, cooled, and 45 ml of 3% H_2O_2 added at room temperature. The mixture was left standing for 20 minutes at room temperature and was then heated for 6 hours at 80°. The dark-yellow solution was acidified with HCl and treated with ether. After removal of ether from the ethereal extract, 0.75 g of a crystalline substance was obtained, which sublimed at 160-170° and 0.02 mm. On subliming, 0.28 g of colorless crystals was obtained, which after recrystallizing from ethyl acetate melted at 220-221°. The substance readily dissolved in water and alcohol, with difficulty in ether and ethyl acetate. A sample mixed with an authentic sample of furan-2,3-dicarboxylic acid gave no melting point depression.

Found %: C 45.94; H 2.64. $C_6H_4O_5$. Calculated %: C 46.15; H 2.58.

SUMMARY

1. The furocoumarin xanthotoxin was obtained in crystalline form from the fruits of the cultivated parsnip, and a chemical investigation of it carried out.

2. To prove the structure of xanthotoxin, a series of its derivatives was prepared and partial synthesis of xanthotoxin from imperatorin achieved.

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INVESTIGATION OF ACONITIC ALKALOIDS

XVIII.* STRUCTURE OF ISOTALATIZIDINE, TALATIZIDINE, CONDELPHINE, AND MONOACETYLZONGORINE

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Isotalatizidine and talatizidine, $C_{23}H_{37}O_5N$ or $C_{19}H_{23}(NC_2H_5)(OCH_3)_2(OH)_3$ have been isolated from the plant Aconitum talassicum by A. P. Orekhov and R. A. Konovalova [2]. Later, from the plant Delphinium confusum the alkaloid condelphine was obtained [11], this being O-monoacetylisotalatizidine. If in the isotalatizidine molecule, and also in the aconitine molecule and that of other polysubstituted aconitic alkaloids ("aconitines") all functional groups are substituted by hydrogen atoms, then in every case a substance of identical composition $C_{19}H_{29}N$ would be obtained. This was first observed by A. P. Orekhov and R. A. Konovalova [2], who proposed that "aconitines" are derivatives of the same substance $C_{19}H_{29}N$. This hypothesis, put forward 20 years ago, has been confirmed by investigation of the structure of licoctonine [3], aconitine [4], delphinine [5], delpheline [6], delcozine [7], delcoline [8], eldeline [9], elatine [10], all based on a common "licoctoninic" nucleus.

We have studied several conversions of isotalatizidine (I) and condelphine (II). The experimental data thus obtained agrees with the hypothesis regarding the presence of a "licoctoninic" nucleus in isotalatizidine, this having been observed in our previous communication [12]. The formulas for isotalatizidine and condelphine proposed by us previously are dealt with more precisely in the present article.

On acetylation of isotalatizidine with acetic anhydride in pyridine at 20° diacetylisotalatizidine is obtained. The third hydroxyl group of isotalatizidine is acetylated only on heating with acetylchloride.

Oxidation of isotalatizidine, according to Kiliani, leads to didehydroisotalatizidine (III), $C_{23}H_{33}O_5N$, containing two carbonyl groups (ν 1752 and 1705 cm^{-1}). On oxidizing isotalatizidine with chromic anhydride in pyridine didehydrooxoisotalatizidine (IV), $C_{23}H_{31}O_6N$, is formed, containing two carbonyl groups and a lactam carbonyl (ν 1752, 1712 and 1633 cm^{-1}). The stability of this latter substance toward oxidation with potassium permanganate in acetone solution indicates that both carbonyl groups are ketonic, i.e., that the two hydroxyl groups of isotalatizidine are secondary. The third OH-group of isotalatizidine is acetylated and oxidized with difficulty and hence is evidently tertiary.

The absorption band frequencies of the keto groups in the infrared spectra of didehydroisotalatizidine (III) and didehydrooxoisotalatizidine (IV) indicate that one of the keto groups is in a 5-membered ring (band 1752 cm^{-1}), the other in a 6-membered ring (bands 1705 and 1712 cm^{-1}). In the corresponding rings, secondary hydroxyl groups also occur.

By catalytic hydrogenation of didehydroisotalatizidine (III) with Raney catalyst, the keto group occurring in the 5-membered ring is reduced, dehydroisotalatizidine (V), $C_{23}H_{35}O_5N$, being formed; in the infrared spectrum of the hydrochloride a band 1702 cm^{-1} occurs (keto group in a 6-membered ring).

On oxidizing isotalatizidine with silver oxide two substances are obtained. One of them is des-N-ethyl-isotalatizidine (VI), this being confirmed by the elementary composition of the substance, $C_{21}H_{33}O_5N$, by conversion on alkylation with ethyl iodide into isotalatizidine, and by preparation of the N-acetyl derivative (VII). The other

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* Previous communication, see [1].

substance, $C_{21}H_{31}O_5N$, contains two hydrogen atoms less than des-N-ethyl-isotalatizidine (VI), and is converted into it by the action of sodium borohydride. The possibility of such a reaction in the absence of carbonyl groups in the substance leads to the proposition that the second substance contains an inner α-carbinolamine ether grouping and is anhydrohydroxy-des-N-ethylisotalatizidine (VIII). In this case, formation of (VIII) can be proposed as the result of oxidation of (VI) to a carbinolamine and of conversion of the latter into an inner ether. This proposition is confirmed by the presence in substance (VIII) of only two hydroxyl groups (in des-N-ethyl-isotalatizidine there are 3 OH-groups) and of a secondary nitrogen atom, which excludes the possibility of presence of C = N-group.[•]

Oxidation of isotalatizidine with potassium permanganate in acetone solution acidified with acetic acid leads to a mixture of substances, mainly of neutral character. Three substances were isolated from the mixture. In greatest yield was obtained substance (IX), $C_{23}H_{31}O_6N$, containing 2 OCH_3, 1 OH, N–CO (ν 1638 cm^{-1}) and a keto group in a 5-membered ring (ν 1753 cm^{-1}). Substance (IX) does not undergo acetylation with acetic anhydride in pyridine and is not oxidized by Kiliani reagent, this indicating the tertiary character of the hydroxyl group contained in its molecule. Substance (IX) also contains an inner α-carbinolamine ether grouping, this following from the possibility of converting (IX) into anhydrohydroxy-des-N-ethylisotalatizidine (VIII). Heating substance (IX) with dilute acid leads to hydrolysis of the N-acetyl group, with formation of the secondary base (X), $C_{21}H_{29}O_5N$, which contains a keto group in a 5-membered ring (ν 1750 cm^{-1}). The secondary base is converted into (IX) on acetylation and into anhydrohydroxy-des-N-ethylisotalatizidine (VIII) on reduction of the keto group by hydrogenation with Raney catalyst. By hydrogenation of substance (IX) under all these conditions, the N-acetate of anhydro-hydroxy-des-N-ethylisotalatizidine (N-acetate of VIII) was obtained. Thus, substance (IX) is N-acetyl-dehydro-anhydrohydroxy-des-N-ethylisotalatizidine. The fact that (IX) contains an inner ether grouping together with a tertiary hydroxyl group and a 5-membered ketone leads to the conclusion that the inner-ethereal grouping in this substance, as in (VIII) and (X), is formed with the assistance of the secondary hydroxyl group occurring in the 6-membered ring.

Dehydro-anhydrohydroxy-des-N-ethylisotalatizidine (X) is stable toward oxidation with Kiliani reagent and oxidation with potassium permanganate in acetone solution, this being in agreement with the proposed absence of secondary hydroxyl groups in this substance.

On oxidation of isotalatizidine with potassium permanganate the following were obtained in lesser amounts: the N-acetate of dehydro-des-N-ethylisotalatizidine (XI), $C_{23}H_{33}O_6N$ [ν 1751 cm^{-1} (5-membered ketone), 1624 cm^{-1} (> NCO)] and the N-acetate of didehydro-des-N-ethylisotalatizidine (XII), $C_{23}H_{31}O_6N$, ν 1700 and 1748 cm^{-1} (6- and 5-membered ketones), 1635 cm^{-1} (> N–CO). As a result of reduction of (XI) with sodium borohydride, the N-acetate of des-N-ethylisotalatizidine (VII) was obtained, and on oxidation with chromic acid –(XII).

Didehydrooxoisotalatizidine (IV) and the N-acetate of didehydro-des-N-ethylisotalatizidine (XII) are isomers; the difference between these substances can be caused only by a different position for the amide carbonyl groups. Since in (XII) this group is in a side chain, in didehydrooxoisotalatizidine it should occur in a 6-membered or a larger-membered ring, this being expected from the absorption frequency in the infrared spectrum occasioned by the presence of this group.

On acetylation of condelphine with acetic anhydride in pyridine a substance is formed identical to diacetyl-isotalatizidine. We have seen that in the diacetylisotalatizidine molecule a tertiary hydroxyl group occurs which was acetylated with difficulty; consequently, the secondary hydroxyl in condelphine is acetylated. According to Kiliani, on oxidation of condelphinedehydrohydroxycondelphin with Kiliani reagent (XIII) was obtained, $C_{25}H_{37}O_7N$, in the infrared spectrum of which occur bands 1745 cm^{-1} (carbonyl of an acetyl group) and 1690 cm^{-1} (6-membered ketone). Substance (XIII) contains one oxygen atom more than condelphine, which fact is connected with the formation of a new hydroxyl group as a result of oxidation, this group occurring next to the nitrogen atom. Such a proposition explains the ability of this hydroxyl group to be reduced on catalytic hydrogenation in acid solution and the ability of the substance to form anhydronium salts (see Experimental). The presence in the oxidation product of condelphine of a 6-membered ketone group indicates that in condelphine the secondary hydroxyl group occurs in a 6-membered ring and that the acetyl group "shelters" the secondary hydroxyl occurring in the 5-membered ring.

[•] Presence of an inner α-carbinolamine ether grouping in (VIII, IX, X) is also confirmed by the presence in the i.r.-spectra of these substances of bands 1000 and 900 cm^{-1} [8].

Name of substance	Value of pK_a
Isotalatizidine (IV)	7.7
Condelphine (II)	7.6
Diacetylisotalatizidine	6.9
Triacetylisotalatizidine	6.3
Dehydroisotalatizidine	5.6
Didehydroisotalatizidine	5.2
Des-N-ethylisotalatizidine	8.5
Anhydrohydroxy-des-N-ethylisotalatizidine	6.4

On dehydrogenation of isotalatizidine with selenium, 1,3-dimethylphenanthrene was obtained. Formation of the hydrocarbon in a case where a "licoctonine" nucleus is present in isotalatizidine can be explained only by determining the position of the two hydroxyl groups in the isotalatizidine molecule. The scheme for such a conversion given below was proposed by K. Vizner during a discussion of our communication on this theme.
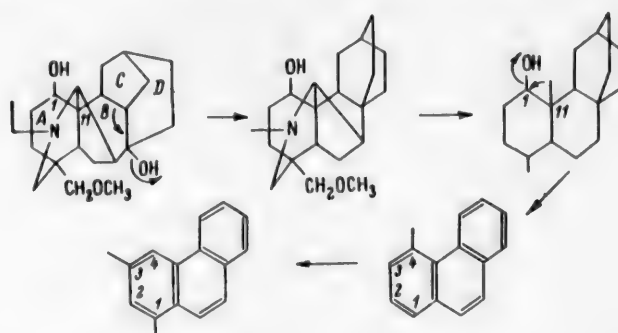
This scheme includes two retropinacoline regroupings, one of which leads to migration of an angular group from position 11 to position 1, the other to enlargement of ring C. A similar conversion during dehydrogenation with selenium is described in the literature. For example, on dehydrogenating Δ^5-androstene-3β,17β-diol an angular group migrates from position 13 to position 17 in place of a hydroxyl group, and another is split off from position 10 [13]. Methyl group migration in a ring is usually connected with the presence of a nearby hydroxyl group [14]. Examples of ring contraction during retropinacoline regrouping are well-known [15]. The final stage in the conversion of isotalatizidine according to the scheme given above is the migration of a methyl group from the spatially-strained 4-position of the phenanthrene nucleus. Such a migration is observed in synthesis of alkyl-phenanthrenes [16].

In determining the position of the hydroxyl groups in the aconitic alkaloid molecule, comparison of the basicity of aminoalcohols, their O-acetates, and of aminoketones—their oxidation products, has been used in a number of cases [4, 17, 18, 21]. It was observed that aminoalcohols possess a higher basicity than their corresponding O-acetates and aminoketones. Decrease in basicity was not noticeable in substances containing carbonyl groups spatially close to a nitrogen atom: for instance, acetylation of the hydroxyl group in alkaloids with a licoctoninic nucleus in position 1 or 6 lowers the value of pK_a by 0.9-1.0 units; oxidation of hydroxy groups in these positions to ketone groups leads to lowering of pK_a by 2-2.5 units.

A comparison carried out by us of the basicity of songorine (pK_a 7.8), monoacetylsongorine (pK_a 7.5), isolated from Aconitum soongoricum [19], and diacetylsongorine (pK_a 6.2) indicates that the acetyl group in mono-acetylsongorine is at some distance from the nitrogen, i.e., evidently occurs at position 19, and not at position 3.
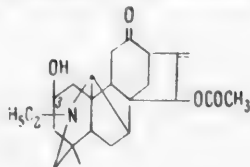
Introduction of an α-carbinolamine inner ether grouping into a molecule has a marked effect on the basicity of the substance. For instance, in delcosine derivatives [18], containing a $C_{16}-O-C_1$ grouping, and in songorine derivatives [20] a decrease in basicity to the extent of 2-3 pK_a units is observed, compared with derivatives not containing such a grouping. Values of pK_a for isotalatizidine derivatives are compared in the table.

The data shown permits the following conclusions. In these substances, acetylation of the hydroxyl group occurring in the 5-membered ring does not result in substantial lowering of basicity: isotalatizidine has pK_a 7.7, condelphine–pK_a 7.6. Acetylation of the secondary hydroxyl group occurring in the 6-membered ring leads to a lowering of the value of pK_a by 0.7 units: condelphine–pK_a 7.6, diacetylisotalatizidine–pK_a 6.9. In isotalatizidine derivatives, oxidation of the secondary hydroxyl group occurring in the 6-membered ring lowers the basicity of the substance markedly: isotalatizidine–pK_a 7.7, dehydroisotalatizidine–pK_a 5.6.

Further oxidation of dehydroisotalatizidine to didehydroisotalatizidine (pK_a 5.2),containing besides a 6-membered ketone grouping also a keto-grouping in a 5-membered ring, causes only a slight lowering of the basicity of the substance (to the extent of 0.4 pK_a units).

This data leads to the proposition that in the isotalatizidine molecule the nitrogen atom is spatially close to the hydroxyl group occurring in the 6-membered ring, and that the nitrogen atom is distant from the hydroxyl group occurring in the 5-membered ring. Position 1 is most likely for the secondary hydroxyl group occurring in the 6-membered ring. In this case, an explanation is obtained for the migration of the methyl group during dehydrogenation, the reduced basicity of diacetylisotalatizidine and dehydroisotalatizidine, the possibility of formation of an inner α-carbinolamine ether with participation of this hydroxyl group and the lowering of basicity observed therewith.

This proposal is also confirmed by certain spectral data. The band of the 6-membered ketone in the spectrum of dehydroisotalatizidine (ν 1686 cm^{-1}) has a lower frequency compared with the frequency of this band in the spectrum of dehydroisotalatizidine hydrochloride (ν 1702 cm^{-1}) and in the spectrum of didehydrooxoisotalatizidine (ν 1712 cm^{-1}). The decrease in frequency of this band in the spectrum of dehydroisotalatizidine can be explained by the reaction of the carbon atom of the ketonic group with the unshared pair of electrons of the nitrogen atom [21, 24]. Salt formation couples the unshared pair of nitrogen electrons. In didehydrooxoisotalatizidine this reaction does not occur because of the stronger reaction of the nitrogen atom with the lactam carbonyl.

In the infrared spectrum of diacetylisotalatizidine two acetyl group carbonyl bands occur. One of these bands has the same frequency as the band of the carbonyl group of condelphine (1734 cm^{-1}), the other having a lower frequency (1720 cm^{-1}). The decrease in absorption frequency of one of the carbonyl groups in the spectrum of diacetylisotalatizidine can be explained by the occurrence of a reaction between carbonyl group and nitrogen atom, and indicates the adjacent position of these groups.

For the secondary hydroxyl group in isotalatizidine occurring in the 5-membered ring, position 19 is the most probable, and positions 6 and 12 less probable, being spatially adjacent to the nitrogen atom. This proposition agrees with the fact that the band frequency of the 5-membered ketone is practically identical in the spectra of the ketones [1752 and 1750 cm^{-1} in the spectra of (III) and (X)] and the oxoketocompounds corresponding to them [1752 and 1753 cm^{-1} in the spectra of (IV) and (IX)].

For the tertiary hydroxyl group in isotalatizidine,position 8 is the most probable. The presence of a hydroxyl group in this position affords an explanation of the rupture of isotalatizidine on dehydrogenation with selenium. This position for the tertiary hydroxyl affords also an explanation of the decrease in basicity of the substance on acetylation of this hydroxyl group, the decrease being close to the observed decrease in basicity on acetylation of the hydroxyl groups adjacent to the nitrogen atom.

(I) R = C₂H₅; R' = H;
(II) R = C₂H₅; R' = COCH₃;
(VI) R = R' = H;
(VII) R = COCH₃; R' = H;
(XIV) R = C₂H₅; R' = H;

(I) $R = C_2H_5$; $R' = H$;
(II) $R = C_2H_5$; $R' = COCH_3$;
(VI) $R = R' = H$;
(VII) $R = COCH_3$; $R' = H$;
(XIV) $R = C_2H_5$; $R' = H$;
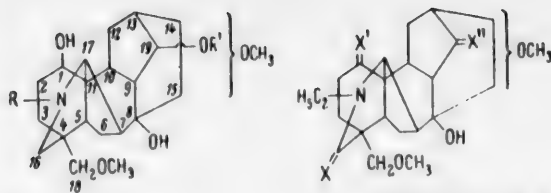
(III) $X = H_2$; $X' = X'' = O$;
(IV) $X = X' = X'' = O$;
(V) $X = H_2$; $X' = O$; $X'' = H + OH$.

(I, II, VI, VII) contain an OH at C_1, in the cis-position to $C_{17}-N-C_{16}$;
(XIV) OH at C_1 trans to $C_{17}-N-C_{16}$.
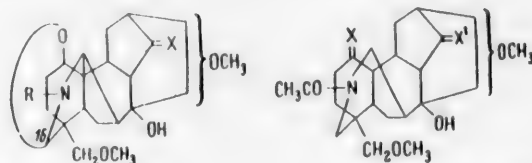
(VIII) $R = H$; $X = H + OH$;
(IX) $R = COCH_3$; $X = O$;
(X) $R = H$; $X = O$;

(XI) $X = H + OH$; $X' = O$;
(XII) $X = X' = O$.

Examination of the spatial models shows that there is not a great difference in the shortest distances between the nitrogen atom and the acetyl groups carbonyls occurring in the axial position at C_6, for instance, in acetyl-delpheline, and at C_8 in the equatorial position, which the acetoxy group of triacetylisotalatizidine can occupy. Such a position for the tertiary hydroxyl group in isotalatizidine does not contradict the possibility of pyrolytic rupture of triacetylisotalatizidine. This reaction proceeds at 190-200°, leading to splitting off of acetic acid and formation of an unsaturated product; it is similar to the pyrolytic rupture of aconitine and delphinine, which contain an acetoxy group in position 8.

In the isotalatizidine molecule there are two OCH_3-groups. One of these evidently occurs at C_{18}, since isotalatizidine contains only one $C-CH_3$-group.

Reduction with sodium borohydride of dehydroisotalatizidine (V), dehydrohydroxycondelphine (XIII), and didehydroisotalatizidine (III), all containing a ketonic group in position 1, leads to an epimer of isotalatizidine which is identical to the alkaloid talatizidine (XIV), pK_a 6.9. The latter thus differs from isotalatizidine only in the orientation of the hydroxyl group at C_1, which in the isotalaltizidine molecule occurs in the cis-position to the $C_{17}-N-C_{16}$ bridge, since only with such a position for this hydroxyl group can be proposed the formation of an inner α-carbinolamine ether grouping.

The data obtained permits the proposal of possible partial formulas for isotalatizidine (I), talatizidine (XIV), condelphine (III), and the other derivatives given above.

EXPERIMENTAL*

Diacetylisotalatizidine. 2 g of isotalatizidine and 6 ml of acetic anhydride were dissolved in 15 ml of pyridine and left for 8 days. 2 g were obtained, m.p. 112-117° (from ether), pK_a 6.9; ν_{max} (CHCl₃) 1720 and 1734 cm^{-1}.

Found %: C 66.43; H 8.51; OCH_3 12.41. $C_{27}H_{41}O_7N$. Calculated %: C 65.98; H 8.41; 2 OCH_3 12.6.

0.5 g of condelphine was acetylated under the same conditions, 0.4 g of diacetylisotalatizidine being obtained.

Triacetylisotalatizidine. The substance was prepared as described; m.p. 131-135° (from hexane), pK_a 6.3; ν_{max}** 1728 and 1742 cm^{-1}.

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* Spectral investigations were carried out by Yu. N. Sheinkep with co-workers in the physical chemistry laboratory of our institute.

** In vaseline oil here and later, where no solvent is indicated.

Didehydroisotalatizidine (III). To 16 g of isotalatizidine in 160 ml of 2% sulfuric acid was added at 20° 105 g of Kiliani solution (10.6 g of chromic anhydride in 80 ml of water with 8.4 g of concentrated sulfuric acid). The mixture was left for 40 hours, made alkaline with 25% ammonia with cooling and extracted with ether. 3 g was obtained, m.p. 128-130° (from acetone), pK_a 5.2; ν_{max} (CHCl$_3$) 1752 and 1705 cm^{-1}, ν_{max} 3430, 1735, 1695 cm^{-1}.

Found %: C 68.76; H 8.08; N 3.28; OCH$_3$ 15.01. C$_{23}$H$_{33}$O$_5$N. Calculated %: C 68.44; H 8.25; N 3.47; 2 OCH$_3$ 15.4.

0.55 g of (III) in 20 ml of 50% methanol was reduced with 0.5 g of sodium borohydride (12 hours at 20°), 0.1 g of isotalatizidine being obtained and 0.2 g of a substance with m.p. 218-220°, a sample of which mixed with talatizidine gave no melting point depression; the two substances had coincident infrared spectra.

Didehydrooxoisotalatizidine (IV). To a solution of 9 g of chromic anhydride in 90 ml of pyridine was added 7 g of isotalatizidine in 10 ml of pyridine. After 20 hours the pyridine was distilled off in vacuo (bath 80-90°), and to the residue added ice, 5% sulfuric acid, and potassium metabisulfite. The solution was extracted with chloroform. The extract was washed with dilute sulfuric acid, caustic soda, and water. After drying and concentration of solvent by evaporation an oily substance was obtained, from which by treatment with acetone was obtained 1.5 g, m.p. 182-183.5° (from acetone with ether); ν_{max} (CHCl$_3$) 1752, 1712, and 1633 cm^{-1}; ν_{max} 3400, 1756, 1709, 1644 cm^{-1}. After 1 hour's boiling with 10% caustic soda and after 3 hour's heating with 10% sulfuric acid a large amount of the substance was recovered unchanged.

Found %: C 65.26; H 7.65; N 3.08; OCH$_3$ 14.95. C$_{23}$H$_{31}$O$_6$N. Calculated %: C 66.18; H 7.49; N 3.36; 2 OCH$_3$ 14.89.

To a solution of 1.1 g (IV) in acetone acidified with acetic acid was added after 5 days 2.5 g of potassium permanganate, 0.8 g of the substance being thereupon recovered unchanged.

0.1 g of (IV) in 5 ml of methanol was reduced with 0.1 g of sodium borohydride, the tetrahydro derivative being obtained, m.p. 204-208° (from ether); ν_{max} 1624 cm^{-1}.

Found %: C 65.65; H 8.12. C$_{23}$H$_{33}$O$_6$N. Calculated %: C 65.86; H 7.93.

Dehydroisotalatizidine (V). 1 g of (IV) in 10 ml of methanol was hydrogenated with Raney catalyst; after 2 hours about 1 mole of hydrogen was absorbed. A noncrystalline base was obtained; ν_{max} 1686 cm^{-1}. Hydrochloride, m.p. 202.5-203° (from anhydrous alcohol containing HCl); pK_a 5.6; ν_{max} 1715 cm^{-1}; ν_{max} (CHCl$_3$) 1702 cm^{-1}.

Found %: C 61.95; H 8.09; Cl 8.07. C$_{23}$H$_{36}$O$_5$NCl. Calculated %: C 62.49; H 8.21; Cl 8.21.

Oxidation of isotalatizidine with silver oxide. Des-N-ethylisotalatizidine (VI) and anhydrohydroxy-des-N-ethylisotalatizidine (VIII). A solution of 3.2 g of isotalatizidine in 150 ml of 30% aqueous methanol was heated for 30 hours on a boiling water bath with silver oxide (from 16 g of AgNO$_3$), filtered and concentrated by evaporation. The residue was dissolved in 5% sulfuric acid, rendered alkaline, and extracted with ether. On concentration by evaporation 0.25 g of (VI) was obtained, m.p. 229-230° (from a mixture of methanol and ether), pK_a 8.5; ν_{max} 3510, 3420, 3270 cm^{-1}.

Found %: C 66.60; H 8.67; N 3.72. C$_{21}$H$_{33}$O$_5$N. Calculated %: C 66.48; H 8.75; N 3.70.

After removal of (VI), the mother liquor was concentrated, and the residue treated with acetone; (VIII) was obtained, m.p. 201-202° (from acetone), pK_a 6.4; ν_{max} 3360, 3300 cm^{-1} (OH), 998, 890 cm^{-1} (inner ether).

Found %: C 66.11; H 8.14; N 3.41; H (labile) 0.74. C$_{21}$H$_{31}$O$_5$N. Calc. % C 66.82; H 8.28; N 3.71; 3 H 0.80.

0.75 g of (VI), 7 ml of pyridine, and 2.5 ml of acetic anhydride were left for 48 hours. The noncrystalline reaction product was dissolved in a mixture of 20 ml of alcohol and 5 ml of 1 N NaOH, and heated for 1 hour at 50°. 0.45 g of the N-acetyl derivative was obtained; m.p. 196-198° (from acetone); ν_{max} 3480, 3300, 1633 cm^{-1}.

Found %: C 66.02; H 8.37. C$_{23}$H$_{35}$O$_6$N. Calculated %: C 65.53; H 8.37.

0.15 g of (VI) and 2 ml of ethyl iodide were heated in a bomb for 12 hours at 100°, isotalatizidine being obtained.

65 mg of (VIII) was reduced with sodium borohydride (65 mg in 5 ml of methanol), (VI) being obtained, m.p. 229-230°.

Oxidation of isotalatizidine with potassium permanganate. N-Acetate of dehydro-anhydrohydroxy-des-N-ethylisotalatizidine (IX), N-Acetate of dehydro-des-N-ethylisotalatizidine (XI), and N-acetate of didehydro-des-N-ethylisotalatizidine (XII). To a solution of 14 g of isotalatizidine in 700 ml of acetone was added after 60 hours 45 g of potassium permanganate (in 5 g lots); with each permanganate addition 50 ml of 10% CH_3COOH solution in acetone was added to the solution. After completion of oxidation the solution was filtered and concentrated (in vacuo toward the end). The residue was dissolved in 100 ml of chloroform and extracted a number of times with 5% sulfuric acid (until the aqueous extract did not react with silicotungstic acid either). After concentration of the chloroform solution and treatment of the residue with acetone, (IX) was obtained; yield 0.7 g; m.p. 217-219° (from acetone); ν_{max} 3360, 1757, 1613, 1000, 895 cm^{-1}, ν_{max} (CHCl$_3$) 1753, 1638 cm^{-1}. After boiling substance (IX) with 10% caustic potash for 1 hour, also after boiling for 30 minutes with 5% HCl, and after 40 hours' treatment with Kiliani reagent, the major portion of the substance was recovered unchanged.

Found %: C 65.65; H 7.60; N 3.23; OCH$_3$ 14.53; OH 4.85. $C_{23}H_{31}O_6N$. Calculated %: C 66.18; H 7.49; N 3.36; 2OCH$_3$ 14.89; 1 OH 4.07.

The aqueous sulfuric acid extract was rendered alkaline with 40% caustic soda and extracted with chloroform. After evaporation of solvent, the oily substance was dissolved in a mixture of acetone and ether; 0.5 g of (XI) was obtained, m.p. 234-236° (from a mixture of methanol and ether); ν_{max} 3233, 3450, 1745, 1621 cm^{-1}; ν_{max} (CHCl$_3$) 1751, 1624 cm^{-1}.

Found %: C 65.48; H 8.02; OCH$_3$ 14.80. $C_{23}H_{33}O_6N$. Calculated %: C 65.86; H 7.93; 2 OCH$_3$ 14.80.

After preparation of (IX) the mother liquors were concentrated; the residue was dissolved in 40 ml of 10% sulfuric acid. The solution was heated for 3 hours on a boiling water bath. From the fraction containing bases 0.7 g of (X) was obtained. From the fraction containing neutral substances was obtained 0.1 g of (XII), m.p. 202-204° (from acetone); ν_{max} 3440, 1730, 1698, 1620 cm^{-1}; ν_{max} (CHCl$_3$) 1748, 1700, 1635 cm^{-1}. The substance was unchanged after treatment with Kiliani reagent and after 40 hours.

Found %: C 66.36; H 7.45; N 3.03; OCH$_3$ 14.13. $C_{23}H_{31}O_6N$. Calculated %: C 66.18; H 7.49; N 3.36; 2OCH$_3$ 14.87.

0.2 g of substance (XI) in 2 ml of glacial acetic acid was oxidized with 0.2 g of chromic anhydride; 0.1 g of (XII) was obtained.

0.15 g of substance (XI) was reduced with 0.15 g of lithium alumohydride in ethereal solution; isotalatizidine was obtained.

To a solution of 0.1 g of substance (XI) in 4 ml of 50% methanol was added 0.1 g of sodium borohydride. After 10 hours, 85 mg of the N-acetate of des-N-ethylisotalatizidine (VII) was obtained, m.p. 195-197°.

Reduction of N-acetate of anhydrohydroxydehydro-des-N-ethylisotalatizidine (IX). 0.15 g of (IX) in 10 ml of methanol was hydrogenated with Pt (from PtO$_2$); the N-acetate of anhydrohydroxy-des-N-ethylisotalatizidine was obtained, m.p. 163-165° (from acetone).

Found %: C 65.08; H 7.88. $C_{23}H_{33}O_6N$. Calculated %: C 65.86; H 7.93.

The latter was also obtained by hydrogenation of 0.2 g of (IX) in 20 ml of methanol with Raney catalyst, m.p. 163-165°; it was also obtained by reducing 0.95 g of (IX) in 50 ml of 50% methanol with 0.95 g of sodium borohydride; yield 0.5 g, m.p. 167-169°.

By reducing substance (IX) with lithium alumohydride in ethereal solution, isotalatizidine was obtained.

A solution of 0.1 g of the N-acetate of anhydrohydroxy-des-N-ethylisotalatizidine in 1.5 ml of 10% sulfuric acid was heated at 100° for 3 hours; anhydrohydroxy-des-N-ethylisotalatizidine (VIII) was obtained, m.p. 196-198°

Dehydro-anhydrohydroxy-des-N-ethylisotalatizidine (X). A solution of 0.5 g of the N-acetate of dehydro-anhydrohydroxy-des-N-ethylisotalatizidine (IX) in 5 ml of 10% sulfuric acid was heated for 3 hours at 100°. 0.3 g of (X) was obtained, m.p. 234-236° (from acetone), pK$_a$ 5.6; ν_{max} 3450, 3280, 1730 cm^{-1}, and 994 and 905 cm^{-1} (inner ether); ν_{max} (CHCl$_3$) 1750 cm^{-1}. After treatment with Kiliani reagent for 40 hours the major portion of the substance was recovered unchanged.

Found %: C 67.77; H 7.77; N 3.96; OCH$_3$ 15.20; H(labile) 0.50; C−CH$_3$ not observed. C$_{21}$H$_{29}$O$_5$N. Calculated %: C 67.19; H 7.79; N 3.74; 2OCH$_3$ 16.45; 2H (labile) 0.53.

A solution of 0.5 g of substance (X) and 1.5 ml of acetic anhydride in 4 ml of pyridine was left for 10 days; 0.45 g of (IX) was obtained, m.p. 220°.

0.5 g of substance (X) in 25 ml of methanol was hydrogenated with Raney catalyst; (VIII) was obtained, m.p. 202-205°.

0.5 g of substance (X) in 20 ml of 50% methanol was reduced with 0.5 g of sodium borohydride, and after 20 hours 0.2 g of (VI) obtained, m.p. 229.5-230.5°.

Dehydrohydroxycondelphine (XIII). 8 g of condelphine was oxidized by the Kiliani method, as for isotalatizidine; the reaction product was treated with 20 ml of boiling ether, and the insoluble fraction removed. The substance obtained after concentrating the ethereal solution was crystallized from acetone; 1 g was obtained, m.p. 124-126°; ν_{max} 1745, 1690 cm^{-1}.

Found %: C 64.96; H 7.88; H (labile) 0.42. C$_{25}$H$_{37}$O$_7$N. Calculated %: C 64.78; H 8.05; 2H (labile) 0.43.

The cloride was prepared by addition of absolute ether to a solution of the base in anhydrous alcohol acidified with hydrochloric acid; the substance was amorphous; ν_{max} 1736, 1719 cm^{-1} (acetyl and ketonic groups), 1698 cm^{-1} ($\overset{+}{N}$ = C group).

Found %: C 61.87; H 8.01; Cl 7.35. C$_{25}$H$_{36}$O$_6$NCl. Calculated %: C 62.29; H 7.52; Cl 7.35.

1 g of substance (XIII) in 5 ml of glacial acetic acid in the presence of several drops of perchloric acid was hydrogenated with Pt (from PtO$_2$). 0.9 g was obtained of a substance with m.p. 157-158°, a sample of which mixed with condelphine showed no melting point depression,and upon saponification of which isotalatizidine was obtained, m.p. 219-221°

Dehydrogenation of Isotalatizidine with Selenium was accomplished by the method described previously [22], from 30 g of isotalatizidine,0.1 g of a hydrocarbon being obtained with m.p. 73.5-74.5°; a mixture of it with 1,3-dimethylphenanthrene melted at the same temperature, and the two substances had coincident infrared spectra. The picrate melted at 157-158°, the styphnate−at 166-167°. 0.1 g of the hydrocarbon was oxidized with potassium ferricyanide by the method described previously [23]. From the oxidation product, insoluble in methanol, was obtained the methyl ester of phenanthrenedicarboxylic-1,3 acid, m.p. 135-136° (from methanol).

Found %: C 73.43; H 5.07. C$_{18}$H$_{14}$O$_4$. Calculated %: C 73.45; H 4.80.

Pyrolysis of Triacetylisotalatizidine. 4.6 g of triacetylisotalatizidine was heated in vacuo at 8-10 mm at 190-200° until evolution of volatile products ceased (about 10 minutes). The reaction product was dissolved in 45 ml of methanol, 9 ml of 50% caustic potash added and boiled for 1 hour. The solvent was evaporated off in vacuo, the residue dissolved in water and extracted with ether. 3 g of an oily substance was obtained, which was dissolved in ether; water was added to the solution. After several days, 0.12 g of a crystalline substance was filtered off, m.p. 102-104°, which decolorized a sulfuric acid potassium permanganate solution; in the infrared spectrum, absorption in the carbonyl group absorption region was absent.

SUMMARY

Possible formulas were proposed for the alkaloids isotalatizidine (I), condelphine (II), and talatizidine (XIV). The position possible for the acetyl group in monoacetylzongorine was determined.

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LETTERS TO THE EDITOR

PHENYL- AND DIPHENYLPHOSPHORUS IODIDES

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I. Hoffmann, in a paper at a general meeting of the Society of German Chemists at Stuttgart on June 25-30, 1960 [1], communicated that on rupture of "phosphobenzene" $(C_6H_5)_4P_4$ by the action of methyl iodide symm. diphenyldiiododiphosphine had been obtained by him, and by the action of benzyl iodide on the latter – phenyldiiodophosphine. In the reference to the paper [1] no properties of the substances or analytical data are given. Both of these substances have been prepared by us by other methods.

Phenyldiiodophosphine was obtained by the action of lithium iodide on phenyldichlorophosphine in benzene solution.

$$C_6H_5PCl_2 + 2LiI \rightarrow 2NaCl + C_6H_5P_{\;2}$$

Phenyldiiodophosphine forms yellow prisms (from benzene), is readily hydrolyzed by moist air, m.p. 162-167° (thermometer bulb in the substance). Its structure is proven by analytical data and conversion into phenylphosphinous acid and the corresponding dipiperidide:

$$(89\%)\; C_6H_5P(NC_5H_{10})_2 \xleftarrow{+4HNC_5H_{10}} C_6H_5PI_2 \xrightarrow{+2H_2O} C_6H_5P(OH)_2\; (94\%)$$
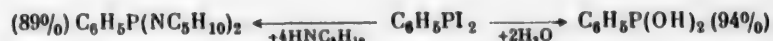
It had been found previously [2] that phosphorus triiodide on reacting with ether is converted into phosphorus diiodide.

$$2PI_3 \xrightarrow{+(C_2H_5)_2O} I_2 + P_2I_4$$

Using this reaction for phenyldiiodophosphine, we obtained symm. diphenyldiiododiphosphine.

$$2C_6H_5PI_2 \xrightarrow{+(C_2H_5)_2O} C_6H_5PI-PIC_6H_5 + I_2.$$

Bright-yellow, fine needles, after sublimation almost colorless m.p. 170-171° (thermometer bulb in the substance).

Found %: P 13.43, 13.10; I 53.35, 54.75. $C_{12}H_{10}P_2I_2$. Calculated %: P 13.19; I 54.04.

Symm. diphenyldiiododiphosphine is obtained directly from phenyldichlorophosphine by reacting the latter with lithium iodide in ethereal solution. By the action of lithium iodide in benzene solution on diphenylchlorophosphine, diphenyliodophosphine is obtained, which gives a complex compound with two molecules of lithium chloride.

$$2(C_6H_5)_2PCl + 2LiI \rightarrow (C_6H_5)_2PI \cdot 2LiCl + (C_6H_5)_2PI$$

The complex $(C_6H_5)_2PI \cdot 2LiCl$ forms colorless, fine prisms, insoluble in nonpolar organic solvents, not melting up to 250°.

Found %: P 7.75, 7.80; $(C_6H_5)_2POOH$ 53.16. $C_{12}H_{10}PLi_2Cl_2I$.   Calculated %: P 7.80; $(C_6H_5)_2POOH$ 54.92.

Diphenyliodophosphine, prepared previously by Issleib and Seidel [3], is a dark-red liquid which is readily hydrolyzed by atmospheric moisture and readily oxidized; identified by conversion into diphenylphosphinic acid in 90.3% yield.

In ethereal solution, reaction of lithium iodide with diphenylchlorophosphine proceeds as in benzene solution. Diphenyliodophosphine is unchanged by boiling with ether.

Thus, phosphorus triiodide and phenyldiiodophosphine are converted by the catalytic action of ether into the corresponding diphosphine derivatives, which do not react with iodine, while tetraphenyldiphosphine is split by iodine into two molecules of diphenyliodophosphine, which is unchanged by the action of ether.

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THE STRUCTURE OF CERTAIN ORGANOTIN POLYMERS

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State University

It has been established that in absence of atmospheric oxygen many reactions proceed with intermediate formation of high-molecular organotin compounds: liquid polymers are formed by disproportionation of hexaethyldistannane (HES) [1] in the course of photochemical decomposition of HES and tetraethyltin, etc. They possess an intense cherry color, are readily oxidized, and, depending on molecular weight, are decomposed into the metal and tetraethyltin at 70-220°. Absence of unpaired electrons in the polymers has been proven by the EPR method. Usual methods of purification and analysis apply to them. In addition, a knowledge of their structure is necessary in understanding the reaction mechanism.

It had been found previously [2] that benzoyl peroxide under mild conditions ruptures the tin-tin bond in HES.

$$(C_6H_5COO)_2 + (C_2H_5)_3Sn-Sn(C_2H_5)_3 \rightarrow 2(C_2H_5)_3SnOCOC_6H_5.$$

It appeared that this reaction could be used in determining the structure of organotin polymers. The reaction proceeds at room temperature without evolution of CO_2 and gaseous hydrocarbons. This points to the absence of side reactions and confirms that in the course of the reaction only the Sn-Sn bonds in polymer and the O-O in the peroxide are ruptured. On reacting the peroxide with the polymer obtained according to the data of [1], we isolated triethyltin benzoate (I) and diethyltin dibenzoate (II) with m.p. 122-123°.

Found %: C 51.89; H 4.94; Sn 27.92. $C_{18}H_{20}O_4Sn$. Calculated %: C 51.59; H 4.81; Sn 28.32.

In addition, metallic tin and ethyltin tribenzoate (III), m.p. 185-188° (decomp.), were obtained.

Found %: C 54.34; H 3.94; Sn 21.66. $C_{23}H_{20}O_6Sn$. Calculated %: C 54.05; H 3.95; Sn 21.82.

If the polymer were a linear one of the type $(C_2H_5)_3Sn-[Sn(C_2H_5)_2]_n-Sn(C_2H_5)_3$, formation would be expected only of (I) (at the expense of primary tin atoms) and (II) (at the expense of secondary ones), since disproportionation of (II) into (I) and (III) does not take place. From the proportions of the amounts of reaction products it is found that 23.6% of the Sn atoms in the polymer are primary, 19.9% secondary, and 27.6% tertiary. In addition, 28.8% of the metallic atoms in the polymeric product are in the elementary state. It is possible that metallic tin is formed at the expense of quaternary atoms. The results obtained agree with the ideas developed previously regarding the branched character of the chains in the intermediate products of disproportionation of HES [1] and hexaethyldiplumbane [3].

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2. G. A. Razuvaev, N. S. Vyazankin, and O. A. Shchepetkova, Zhur. Obshchei Khim. 30, 2498 (1960).
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ANIONOTROPIC REGROUPING ON REACTING β-CHLOROPROPIONIC ACID WITH PHOSPHORIC ANHYDRIDE

R. G. Kostyanovskii

It is known that when reacted with P_2O_5, malonic acid [1] and its derivatives [2], unlike carboxylic acids with less labile hydrogen atoms, undergo intramolecular dehydration, for instance:
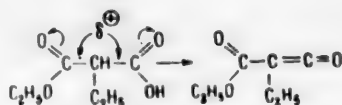
In the case of β-chloropropionic acid (I), in which the α-position is activated by the inductive influence of the halogen, formation of chloromethylketene could be expected as a result of a similar effect, the ketene being a representative of halomethylketenes unknown in the literature. However, on heating (150-200°) (I) with P_2O_5 we obtained acryloyl chloride (III).
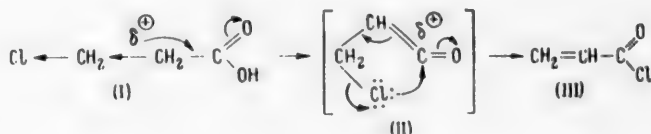
Yield of (III) 32-43%, b.p. 72-72.5° (data in the literature: b.p. 72-73° [3], 72-74° [4]), $n_D^{21.8}$ 1.4340, $d_4^{21.8}$ 1.1043, MR 21.34; calc. 20.83. The product was titrated with two moles of alkali.

Found %: Cl 39.0, 39.12. M (in benzene, cryoscop. 87. C_3H_3OCl. Calculated %: Cl 39.17. M 90.52.

By reacting (III) with NH_3 in benzene an amide was obtained, m.p. 84°. A sample mixed with the authentic amide of acrylic acid gave no melting point depression.

The mechanism of the reaction can evidently be explained by anionotropic regrouping of chloromethylketene via an intermediate condition (II) with the halogen attacking the positively polarized carbonyl carbon and formation of a stable conjugated system (III).

The usual methods for synthesis of acid chlorides of carboxylic acids (treatment with $SOCl_2$, PCl_3, PCl_5, or $POCl_3$) were not used for preparing (III) [4], so the method suggested can be used in addition to those mentioned in the literature [3-5].

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VINYL- AND PHENYLACETYLENYLTROPILIDENES

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Translated from Zhurnal Obshchei Khimii, Vol. 31, No. 4,
p. 1403, April, 1961
Original article submitted January 14, 1961

With the aim of studying the possibility of synthesizing tropilium salts with unsaturated radicals we have prepared vinyl- and phenylacetylenyltropilidenes by the action of bromovinylmagnesium- and phenylacetylenyls on tropyl bromide.

Vinylacetylenyltropilidene. Colorless liquid, b.p. 74-75° (5 mm), d_4^{20} 0.9310, n_D^{20} 1.5622.

Found %: C 92.91, 92.58; H 7.10, 7.15. $C_{11}H_{10}$. Calculated %: C 92.91; H 7.09.

I.r.-spectrum (main frequencies): 700 v.s, 742 s, 794 m, 920 v.s, 972 s, 1168 m, 1278 s, 1390 s, 1413 m, 1610 s, 1648 w, 1845 w, 2235 s, 2833 m, 3010 s, 3028 s, 3098 m cm^{-1}.

In the mass-spectrum of the substance (taken by A. A. Polyakova and R. A. Khmel'nitskii) the ion $C_{11}H_9^+$ has the highest intensity. An intensity greater than 20% of the maximum is also possessed by ions with masses 142 (38%), 115 (64%), and 63 (31%).

Phenylacetylenyltropilidene. Colorless liquid with an aromatic odor. B.p. 135-137° (4 mm), d_4^{20} 1.0230, n_D^{20} 1.6140.

Found %: C 93.09; H 6.54. $C_{15}H_{12}$. Calculated %: C 93.71; H 6.29.

I.r.-spectrum (main frequencies): 692 v.s, 742 s, 752 v.s, 875 w, 912 m, 980 m, 1019 w, 1067 m, 1290 s, 1388 m, 1440 s, 1487 s, 1597 s, 1632 m, 2232 w, 2833 w, 2962 m, 3020 v.s, 3050 s, 3075 m cm^{-1}.

Since the infrared spectra of the compounds obtained contain all the basic frequencies of the tropilidene ring [1] and the acetylene residue [2, 3], their structure is not open to doubt. The acetylene bond in both substances is linked with only one double bond or phenyl nucleus, since in the case of double and even more so in the case of triple linkage the frequency of this bond is considerably lower (2200 cm^{-1}) [4]. Consequently, no isomerization with bond shifting in the ring occurs in synthesis of acetylenyltropilidenes, nor in other similar cases [5].

The authors express their thanks to M. E. Vol'pin for help in the work.

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DISCUSSION

THE PROBLEM OF INVESTIGATING SPECIAL CASES
OF LIQUID SEPARATION

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An article by I. L. Krupatkin published previously,[*] entitled "An Investigation of Special Cases of Liquid Separation," presents a theory on new types of phase diagrams for ternary systems with destruction of solubility of the liquid phases. It seems to us that the theory developed by the author does not agree with the facts.

I. L. Krupatkin's theoretical reasoning is based on experimental data obtained by him on solubility in the system diethylamine − chloral hydrate − water. We have no objections to the author's experimental data, but object categorically to the interpretation he gives to the phenomena observed, and upon which he develops his theory.

Similarly to the author, we discuss his experimental data, give to it a different interpretation and thus demonstrate the untenability of the theory of special cases of liquid separation.
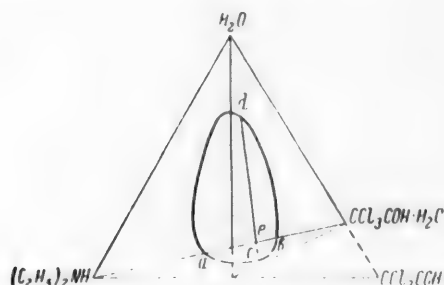
I. L. Krupatkin maintains that the system diethylamine − chloral hydrate is a binary system similar to actual binary systems in which the constituent chemical compounds melt with resolution into two liquid phases. Actually, this system is a section of the ternary system diethylamine − chloral−water, in which an exchange substitution reaction takes place: chloral hydrate + diethylamine = chloraldiethylammonia + water. The system chloral hydrate − diethylamine is not a stable diagonal of the trapezium which is the geometrical representation of the exchange substitution reaction indicated above (see schematic diagram). On the strength of this, the isothermic points on the arms of the binodal curve of the region of separation in the system chloral hydrate − diethylamine cannot be connected points such as occur in actual binary systems with separation. Thus, for instance, points a and b in our diagram are not connected with each other.

The region of separation studied by I. L. Krupatkin in the system diethylamine − chloral hydrate − water is actually a portion of the aggregate ternary system diethylamine − chloral − water (diagram). Of the three homogeneous boundary systems it possesses, the system diethylamine − chloral possesses the highest chemical reactivity between components. It predominates and creates conditions for the existence of a closed binodal curve. The dotted portion of this binodal curve is not fictitious, as thought by I. L. Krupatkin, but actually a real line. The nodes of the region of separation are directed toward the predominating binary system diethylamine − chloral. The endpoints of the co-nodes not lie on the section a -b, but are found on the extension of the binodal curve a-c-b. Point e, corresponding to the mixture of diethylamine and chloral hydrate determined, does not decompose according to the presence or absence of water in a + b or e + d as the author of the article asserts, but always decomposes according to the scheme e = d + c because of the occurrence of the mutual substitution reaction indicated above.

Thus, the system investigated by I. L. Krupatkin does not break any new ground. It is a subordinate part of an aggregate ternary system, the geometrical form of the region of separation of which is at present quite well-known. The development of a theory by the author is clearly unnecessary and does not apply to known ternary systems.

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[*] See Zhur. Obshchei Khim. 29, 3523 (1959).

Soviet Journals Available in Cover-to-Cover Translation

ABBREVIATION	RUSSIAN TITLE	TITLE OF TRANSLATION	PUBLISHER	Vol.	Issue	Year
AÉ	Atomnaya énergiya	Soviet Journal of Atomic Energy	Consultants Bureau	1	1	1956
Akust. zh.	Akusticheski zhurnal	Soviet Physics – Acoustics	American Institute of Physics	1	1	1955
	Antibiotiki	Antibiotics	Consultants Bureau	4	1	1959
Astr(on). zh(urn).	Astronomicheskii zhurnal	Soviet Astronomy—AJ	American Institute of Physics	34	1	1957
Avto(mat). svarka	Avtomaticheskaya svarka	Automatic Welding	British Welding Research Association (London)			
	Avtomatika i Telemekhanika	Automation and Remote Control	Instrument Society of America	27	1	1959
	Biofizika	Biophysics	National Institutes of Health*		1	1956
	Biokhimiya	Biochemistry	Consultants Bureau	21	1	1957
Byull. éksp(erim). biol. i med.	Byulleten' éksperimental'noi biologii i meditsiny	Bulletin of Experimental Biology and Medicine	Consultants Bureau		1	1956
DAN (SSSR) Dokl(ady) AN SSSR	Doklady Akademii Nauk SSSR	The translation of this journal is published in sections, as follows:		41	1	1959
		Doklady Biochemistry Section	American Institute of Biological Sciences	106	1	1956
		Life Sciences — Doklady Biological Sciences Sections (Includes: Anatomy, biophysics, cytology, ecology, embryology, endocrinology, evolutionary morphology, genetics, histology, hydrobiology, microbiology, morphology, parasitology, physiology, zoology sections)	American Institute of Biological Sciences	112	1	1957
		Doklady Botanical Sciences Sections (Includes: Botany, phytopathology, plant anatomy, plant ecology, plant embryology, plant physiology, plant morphology sections)				
		Chemical Sciences — Proceedings of the Academy of Sciences of the USSR, Section: Chemical Technology	American Institute of Biological Sciences	112	1	1957
		Proceedings of the Academy of Sciences of the USSR, Section: Chemistry	Consultants Bureau	106	1	1956
		Proceedings of the Academy of Sciences of the USSR, Section: Physical Chemistry	Consultants Bureau	106	1	1956
		Earth Sciences — Doklady Earth Sciences Sections (Includes: Geochemistry, geology, geophysics, hydrogeology, mineralogy, paleontology, petrography, permafrost sections)	Consultants Bureau	112	1	1957
		Proceedings of the Academy of Sciences of the USSR, Section: Geochemistry	American Geological Institute	124	1	1959
		Proceedings of the Academy of Sciences of the USSR, Sections: Geology	Consultants Bureau	106-123	1	1957-1958
		Mathematics — Doklady Soviet Mathematics	Consultants Bureau	106-123	6	1957-1958
		Physics — Soviet Physics—Doklady (Includes: Aerodynamics, astronomy, crystallography, cybernetics and control theory, electrical engineering, energetics, fluid mechanics, heat engineering, hydraulics, mathematical physics, mechanics, physics, technical physics, theory of elasticity sections)	The American Mathematics Society	131	1	1961
		Proceedings of the Academy of Sciences of the USSR, Applied Physics Sections (does not include mathematical physics or physics sections)	American Institute of Physics	106	1	1956
Derevoobrabat. prom-st'.	Derevoobrabatyvayushchaya promyshlennost'	Wood Processing Industry	Consultants Bureau	106-117	1	1956-1957
	Élecktrosvyaz	Telecommunications	Timber Development Association (London)			
Éntom(ol). oboz(renie)	Entomologicheskoe obozrenie	Entomological Review	Massachusetts Institute of Technology*			
Farmakol. (i) toksikol(ogiya)	Farmakologiya i toksikologiya	Pharmacology and Toxicology	American Institute of Biological Sciences	38	9	1959
FMM	Fizika metallov i metallovedenie	Physics of Metals and Metallography	Consultants Bureau	20	1	1957
Fiziol. zhurn. SSSR (im. Sechenova)	Fiziologicheskii zhurnal im. I. M. Sechenova	Sechenov Physiological Journal USSR	Acta Metallurgica*	5	1	1959
Fiziol(ogiya) rast.	Fiziologiya rastenii	Plant Physiology	National Institutes of Health*	4	1	1957
	Geokhimiya	Geochemistry	American Institute of Biological Sciences		1	1957
FTT	Fizika tverdogo tela	Soviet Physics—Solid State	The Geochemical Society		1	1958
Izmerit. tekh(nika)	Izmeritel'naya tekhnika	Measurement Techniques	American Institute of Physics	1	1	1959
Izv. AN SSSR O(td). Kh(im). N(auk)	Izvestiya Akademii Nauk SSSR: Otdelenie khimicheskikh nauk	Bulletin of the Academy of Sciences of the USSR: Division of Chemical Sciences	Instrument Society of America		1	1959
			Consultants Bureau	1		1952

Abbreviation	Title (transliterated)	English Title	Translation Publisher			Year
Izv. AN SSSR, O(td). T(ekhn). N(auk): Met(all). i top.	(see Met. i top.)					
Izv. AN SSSR Ser. fiz(ich).	Izvestiya Akademii Nauk SSSR: Seriya fizicheskaya	Bulletin of the Academy of Sciences of the USSR: Physical Series	Columbia Technical Translations		1	1954
Izv. AN SSSR Ser. geofiz.	Izvestiya Akademii Nauk SSSR: Seriya geofizicheskaya	Bulletin (Izvestiya) of the Academy of Sciences USSR: Geophysics Series	American Geophysical Union		1	1954
Izv. AN SSSR Ser. geol.	Izvestiya Akademii Nauk SSSR: Seriya geologicheskaya	Izvestiya of the Academy of Sciences of the USSR: Geologic Series	American Geological Institute		1	1958
Kauch. i rez.	Kauchuk i rezina	Soviet Rubber Technology	Research Association of British Rubber Manufacturers			
	Kinetika i kataliz	Kinetics and Catalysis	Consultants Bureau	18	1	1959
	Koks i khimiya	Coke and Chemistry USSR	Coal Tar Research Association (Leeds, England)	1	3	1960
Kolloidn. zh(urn).	Kolloidnyi zhurnal	Colloid Journal	Consultants Bureau	14	1	1958
	Kristallografiya	Soviet Physics – Crystallography	American Institute of Physics	2	1	1952
Metalov. i term. obrabot. metal.	Metallovedenie i termicheskaya obrabotka metallov	Metal Science and Heat Treatment of Metals	Acta Metallurgica	6	1	1957
	Metallurg	Metallurgist	Acta Metallurgica		1	1958
Met. i top.	Metallurgiya i toplivo	Russian Metallurgy and Fuels	Eagle Technical Publications		1	1957
Mikrobiol.	Mikrobiologiya	Microbiology	American Institute of Biological Sciences	26	1	1960
OS	Optika i spektroskopiya	Optics and Spectroscopy	American Institute of Physics		6	1957
	Pochvovedenie	Soviet Soil Science	American Institute of Biological Sciences		1	1959
	Priborostroenie	Instrument Construction	British Scientific Instrument Research Association		1	1958
Pribory i tekhn. éks(perimenta)	Pribory i tekhnika éksperimenta	Instruments and Experimental Techniques	Instrument Society of America		1	1959
Prikl. matem. i mekh.	Prikladnaya matematika i mekhanika	Applied Mathematics and Mechanics	American Society of Mechanical Engineers		1	1957
PTÉ	(see Pribory i tekhn. éks.)					
	Problemy Severa	Problems of the North	National Research Council of Canada		1	1958
Radiotekh.	Radiotekhnika	Radio Engineering	Massachusetts Institute of Technology*	12	1	1957
Radiotekh. i élektronika	Radiotekhnika i élektronika	Radio Engineering and Electronics	Massachusetts Institute of Technology*	2	1	1957
	Stanki i instrument	Machines and Tooling	Production Engineering Research Assoc.		1	1959
	Stal'	Stal' (in English)	Iron and Steel Institute		1	1959
Stek. i keram.	Steklo i keramika	Glass and Ceramics	Consultants Bureau	13	1	1956
Svaroch. proiz-vo	Svarochnoe proizvodstvo	Welding Production	British Welding Research Association		1	1959
Teor. veroyat. i prim.	Teoriya veroyatnostei i ee primenenie	Theory of Probability and Its Applications	Society for Industrial and Applied Mathematics		4	1956
Tsvet. Metally	Tsvetnye metally	Nonferrous Metals	Primary Sources		1	1960
UFN	Uspekhi fizicheskikh Nauk	Soviet Physics – Uspekhi (partial translation)	American Institute of Physics	66	1	1958
UKh	Uspekhi khimii	Russian Chemical Reviews	The Chemical Society (London)	15	1	1960
UMN	Uspekhi matematicheskikh nauk	Russian Mathematical Surveys	London Mathematical Society		1	1960
Usp. fiz. nauk	(see UFN)					
Usp. khim(ii)	(see UKh)					
Usp. matem. nauk	(see UMN)					
Usp. sovr. biol.	Uspekhi sovremennoi biologii	Russian Review of Biology	Oliver and Boyd		48	1959
Vest. mashinostroeniya	Vestnik mashinostroeniya	Russian Engineering Journal	Production Engineering Research Assoc.		4	1959
Vop. gem. i per. krovi	Voprosy gematologii i perelivaniya krovi	Problems of Hematology and Blood Transfusion	National Institutes of Health*		1	1957
Vop. onk.	Voprosy onkologii	Problems of Oncology	National Institutes of Health*	25	1	1957
Vop. virusol.	Voprosy virusologii	Problems of Virology	National Institutes of Health*	7	1	1957
Zav(odsk). lab(oratoriya).	Zavodskaya laboratoriya	Industrial Laboratory	Instrument Society of America		1	1959
ZhAKh Zh. anal(it). khimii	Zhurnal analiticheskoi khimii	Journal of Analytical Chemistry USSR	Consultants Bureau		1	1952
ZhETF Zh. éksperim. i teor. fiz.	Zhurnal éksperimental'noi i theoreticheskoi fiziki	Soviet Physics–JETP	American Institute of Physics	28	1	1955
ZhFKh Zh. fiz. khimii	Zhurnal fizicheskoi khimii	Russian Journal of Physical Chemistry	The Chemical Society (London)		7	1959
ZhMÉi Zh(urn). mikrobiol. épidemiol. i immunobiol.	Zhurnal mikrobiologii, épidemiologii i immunobiologii	Journal of Microbiology, Epidemiology and Immunobiology	National Institutes of Health*		1	1957
ZhNKh Zh(urn). neorgan(ich). khimi(i)	Zhurnal neorganicheskoi khimii	The Russian Journal of Inorganic Chemistry	The Chemical Society (London)		1	1959
ZhOKh Zh(urn). obshch(ei) khimii	Zhurnal obshchei khimii	Journal of General Chemistry USSR	Consultants Bureau	19	1	1949
ZhPKh Zh(urn). prikl. khimii	Zhurnal prikladnoi khimii	Journal of Applied Chemistry USSR	Consultants Bureau	23	1	1950
ZhSKh Zh(urn). strukt. khimii	Zhurnal strukturnoi khimii	Journal of Structural Chemistry	Consultants Bureau	1	1	1960
ZhTF Zh(urn). tekhn. fiz.	Zhurnal teknicheskoi fiziki	Soviet Physics–Technical Physics	American Institute of Physics	26	1	1956
Zh(urn). vyssh. nervn. deyat. (im. Pavlova)	Zhurnal vysshei nervnoi deyatel'nosti (im. I. P. Pavlova)	Pavlov Journal of Higher Nervous Activity	National Institutes of Health*		1	1958

*Sponsoring organization. Translation through 1960 issues is a publication of Pergamon Press.

SIGNIFICANCE OF ABBREVIATIONS MOST FREQUENTLY
ENCOUNTERED IN SOVIET PERIODICALS

FIAN	Phys. Inst. Acad. Sci. USSR
GDI	Water Power Inst.
GITI	State Sci.-Tech. Press
GITTL	State Tech. and Theor. Lit. Press
GONTI	State United Sci.-Tech. Press
Gosenergoizdat	State Power Press
Goskhimizdat	State Chem. Press
GOST	All-Union State Standard
GTTI	State Tech. and Theor. Lit. Press
IL	Foreign Lit. Press
ISN (Izd. Sov. Nauk)	Soviet Science Press
Izd. AN SSSR	Acad. Sci. USSR Press
Izd. MGU	Moscow State Univ. Press
LEIIZhT	Leningrad Power Inst. of Railroad Engineering
LET	Leningrad Elec. Engr. School
LETI	Leningrad Electrotechnical Inst.
LETIIZhT	Leningrad Electrical Engineering Research Inst. of Railroad Engr.
Mashgiz	State Sci.-Tech. Press for Machine Construction Lit.
MEP	Ministry of Electrical Industry
MES	Ministry of Electrical Power Plants
MESEP	Ministry of Electrical Power Plants and the Electrical Industry
MGU	Moscow State Univ.
MKhTI	Moscow Inst. Chem. Tech.
MOPI	Moscow Regional Pedagogical Inst.
MSP	Ministry of Industrial Construction
NII ZVUKSZAPIOI	Scientific Research Inst. of Sound Recording
NIKFI	Sci. Inst. of Modern Motion Picture Photography
ONTI	United Sci.- Tech. Press
OTI	Division of Technical Information
OTN	Div. Tech. Sci.
Stroiizdat	Construction Press
TOE	Association of Power Engineers
TsKTI	Central Research Inst. for Boilers and Turbines
TsNIEL	Central Scientific Research Elec. Engr. Lab.
TsNIEL-MES	Central Scientific Research Elec. Engr. Lab.-Ministry of Electric Power Plants
TsVTI	Central Office of Economic Information
UF	Ural Branch
VIESKh	All-Union Inst. of Rural Elec. Power Stations
VNIIM	All-Union Scientific Research Inst. of Metrology
VNIIZhDT	All-Union Scientific Research Inst. of Railroad Engineering
VTI	All-Union Thermotech. Inst.
VZEI	All-Union Power Correspondence Inst.

NOTE: Abbreviations not on this list and not explained in the translation have been transliterated, no further information about their significance being available to us. —Publisher.